

COORDINATORS:

Assoc. Prof. **Sorina-Mihaela BĂLAN** Ph.D.

Assoc. Prof. **Doina DAVID** Ph.D.

ARTIFICIAL INTELLIGENCE - THE ENGINE OF EDUCATIONAL INNOVATION IN LAW, PSYCHOLOGY, MEDICINE, GEOGRAPHY AND ECONOMIC SCIENCES

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INNOVATION IN EDUCATION IN A WORLD OF CONSTANT CHANGE

November 24–25, 2025



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Associate Professor Sorina-Mihaela BĂLAN Ph.D.
Associate Professor Doina DAVID Ph.D.

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Editor

Associate Professor Sorina-Mihaela BĂLAN Ph.D.

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FOREWORD

In the 21st century, contemporary universities face an unprecedented challenge, both epistemological and practical: the integration of artificial intelligence (AI) across all its cognitive, institutional, and ethical dimensions within teaching, learning, and research. The international conference “Artificial Intelligence - The Engine of Educational Innovation in Law, Psychology, Medicine, Geography and Economic Sciences” bringing together participants from multiple universities across Europe and Asia, with diverse academic traditions and cultural experiences, occupies a central position at this critical intersection of technology and the university’s mission. This volume is the product of these discussions and analyses, offering a nuanced and comprehensive perspective on how AI can and should contribute to redefining the role of universities in a globalized society.

We are living in a period where AI-based tools are rapidly surpassing their initial role as technological aids, transforming pedagogical practices, curricular strategies, and the relationships between students and faculty. In this context, the university as a space for critical inquiry, rigorous experimentation, and the cultivation of advanced competencies emerges not merely as a recipient of technological innovation, but as an active participant in shaping the development and application of AI. The faculty and practitioners featured in this collection explore precisely this dynamic: how AI can be integrated into higher education in ways that enhance the quality of teaching and learning, while safeguarding the core values of critical thinking, intellectual autonomy, and academic responsibility.

The contributions assembled here reflect a broad range of perspectives and methodologies: from empirical research investigating students’ and instructors’ perceptions of AI tools to conceptual frameworks that situate university pedagogy in dialogue with emerging cognitive technologies. Despite this diversity, a common concern unites them: grounding AI adoption on solid principles, ensuring that technology serves the aims of higher education rather than dictating them. Emphasis is placed on AI’s potential to support active learning, formative assessment, personalized educational pathways, and interdisciplinary collaboration dimensions that embody both technological possibilities and profound pedagogical commitments. Reflecting on the role of universities in the AI era also requires a critical consideration of the risks and limitations of these technologies: from concerns over academic integrity and assessment standards, to their impact on creativity, critical thinking, and interpersonal relationships within academic communities. Such considerations do not diminish the value of innovation; rather, they complement it, ensuring that AI integration is responsible, transparent, and aligned with the fundamental objectives of higher education.

This volume is, above all, an invitation to interdisciplinary and international dialogue at the intersection of educational theory, cognitive science, philosophy of technology, and everyday university practice. Readers will find in these pages not only research findings, but also conceptual frameworks and critical reflections designed to inspire new practices and research directions in universities worldwide.

*As **Priten Shah** notes in one of his recent works on the future of education in the AI era: “Inquiry-based learning: AI can support inquiry-based learning experiences by encouraging students to engage in higher-order thinking skills such as analysis, evaluation, and synthesis.”*

This statement captures a central challenge for contemporary universities: the goal is not merely to use AI as a tool, but to integrate it in ways that enhance students' ability to think critically, conduct research, and generate knowledge that is meaningful and relevant for the 21st century.

Assoc. Prof. Marinela Doina DAVID

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PART I. LAW SECTION

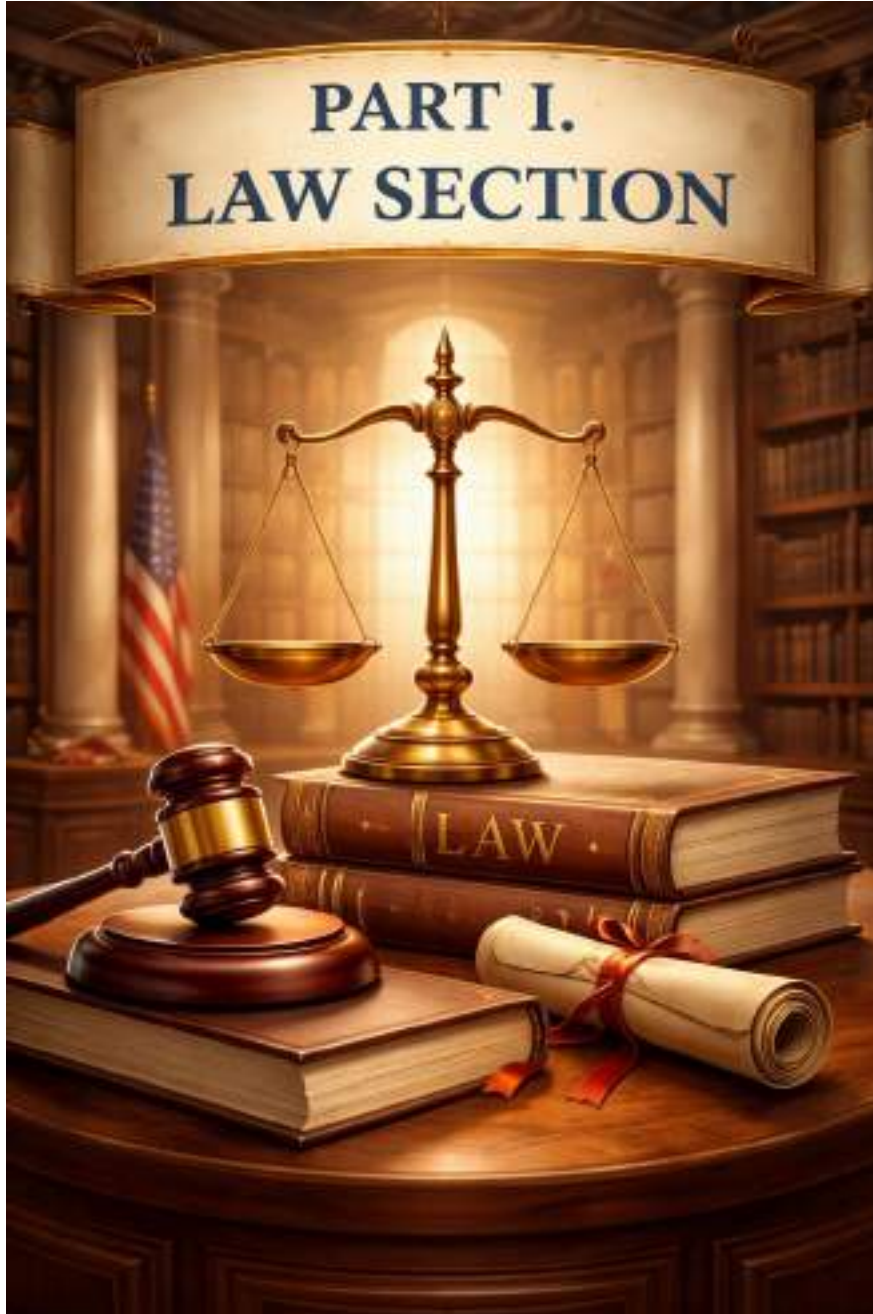


Figure P1. Law Section — Justice, Ethics, and Legal Foundations

This illustrative plate was created collaboratively by S.M. Bălan and an AI-assisted design system to visually represent the conceptual and normative foundations of the legal sciences section.

ABOUT REGULATION (EU) 2024/1689 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL LAYING DOWN HARMONISED RULES ON ARTIFICIAL INTELLIGENCE

Lect. univ. Natalia SAHAROV Ph. D.; Asist. univ. Andrei Bogdan MURGU Ph.D.

*"Dimitrie Cantemir" University of Târgu Mureș, Târgu Mureș, Faculty of Law, Romania
Corresponding author - Natalia SAHAROV: sanav2003@yahoo.com*

Abstract

The proposed study is mainly dedicated to reporting the adoption and (partial) entry into force of Regulation 2024/1689 of the European Parliament and of the Council laying down harmonised rules on artificial intelligence (the Artificial Intelligence Regulation). After recalling certain important moments in the process of regulating artificial intelligence (AI) at the level of Europe and the European Union (EU), we will present the normative structure of the Regulation on Artificial Intelligence (RIA), its entry into force and application, and finally we will present the meaning of the concept of "AI system" offered by the RIA.

Keywords: intelligence, artificial intelligence, artificial intelligence risk levels, robot judge.

Preliminary Remarks

At European level, the Council of Europe drafted in 2020 the *White Paper on Artificial Intelligence – A European Approach to Excellence and Trust* [1]. Subsequently, on 5 September 2024, in Vilnius (Lithuania), the same body adopted the *Framework Convention on Artificial Intelligence, Human Rights, Democracy and the Rule of Law* [2]. According to Article 1(1), “the provisions of this Convention seek to ensure that activities within the lifecycle of artificial intelligence systems are fully compatible with human rights, democracy and the rule of law”. The Convention addresses the member states of the Council of Europe [3], other signatory states, and was also transmitted to the European Union, as well as to certain invited states [4].

On 13 June 2024, Regulation (EU) 2024/1689 of the European Parliament and of the Council laying down harmonised rules on artificial intelligence [5] and amending certain regulations (the Artificial Intelligence Regulation – AIR) was adopted. It should be noted that, pursuant to Article 288(2) of the Treaty on the Functioning of the European Union (TFEU) [6], “a regulation shall have general application. It shall be binding in its entirety and directly applicable in all Member States”. In the case of the AIR, this rule is reiterated by Article 113, final paragraph [7].

Previously, on 21 April 2021, the European Commission adopted the *Proposal for a Regulation of the European Parliament and of the Council laying down harmonised rules on artificial intelligence (Artificial Intelligence Act) and amending certain Union legislative acts* [8]. Numerous provisions of this Proposal were taken over into the AIR [9].

Returning to the AIR, Article 113 establishes rules on its entry into force and application. Thus, pursuant to paragraph (1), the AIR entered into force on the twentieth day following its

publication in the Official Journal of the European Union (namely on 2 August 2024) and shall apply from 2 August 2026.

However, pursuant to paragraph (3) letters (a) - (c), Chapter I (Articles 1 - 4, general provisions), Chapter II (Article 5 – prohibited AI practices), Chapter III, Section 4 (Articles 28–32, notifying authorities and notified bodies), Chapter V (Articles 51–56, general-purpose AI models), Chapter VII (Articles 64–70, governance), Chapter XII (Articles 99–101, penalties) and Article 78 (confidentiality) shall apply from 2 February 2025. Article 101 (fines for providers of general-purpose AI systems) is excluded. Finally, Article 6 Para. (1) [10] and the corresponding obligations of the AIR shall apply from 2 August 2027.

From a structural perspective, the AIR comprises 13 chapters: Chapter I (Articles 1–4) – general provisions; Chapter II (Article 5) – prohibited AI practices; Chapter III (Articles 6–49) – high-risk AI systems; Chapter IV (Article 50) – transparency obligations for providers and deployers of certain AI systems; Chapter V (Articles 51–56) – general-purpose AI models; Chapter VI (Articles 57–63) – measures to support innovation; Chapter VII (Articles 64–70) – governance; Chapter VIII (Article 71) – EU database for high-risk AI systems; Chapter IX (Articles 72–94) – post-market monitoring, information sharing and market surveillance; Chapter X (Articles 95–96) – codes of conduct and guidelines; Chapter XI (Articles 97–98) – delegation of powers and committee procedure; Chapter XII (Articles 99–101) – penalties; Chapter XIII (Articles 102–103) – final provisions. In addition, the AIR contains 13 annexes, which form an integral part thereof.

The AIR explicitly amends a significant number of directives [12] and regulations [13] and, also, entails the harmonisation of numerous legislative acts (implicit amendments) [14]. Undoubtedly, this situation involves a considerable effort, both at EU level and at the level of the Member States, to adapt legislation in various fields.

According to Recital 1, the purpose of the AIR “is to improve the functioning of the internal market [15] by laying down a uniform legal framework, in particular for the development, placing on the market, putting into service and use of artificial intelligence systems in the Union, in accordance with Union values [16], to promote the uptake of trustworthy and human-centric artificial intelligence, while ensuring a high level of protection of health, safety and fundamental rights as enshrined in the Charter of Fundamental Rights of the European Union [17]..., including democracy, the rule of law and environmental protection, to protect against the harmful effects of AI systems in the Union, and to support innovation”. The AIR also “ensures the free cross-border movement of AI-based goods and services, thus preventing Member States from imposing restrictions on the development, marketing and use of AI systems, unless explicitly authorised by this Regulation”. In this context, it should be noted that the AIR is based on no fewer than 180 recitals.

In Romania, the *National Strategy in the Field of Artificial Intelligence 2024–2027* has been drafted and adopted [18]. Moreover, in light of the Proposal for a Regulation, the Romanian Senate adopted Decision no. 110/2021 of 14 September 2021 [19]. The Proposal responded to explicit requests from the European Parliament and the European Commission, which repeatedly called for legislative measures to ensure the proper functioning of the internal market for artificial intelligence systems (“AI systems”), in which both the benefits and risks of AI are adequately addressed at Union level.

At the time of the study, several legislative proposals concerning AI are pending before the Romanian Parliament. For example, we mention the “legislative proposal on the responsible use of artificial intelligence” [20]. The object of regulation consists in ensuring transparency and accountability in the use of AI, protecting the fundamental rights and freedoms of citizens,

preventing the abusive use of AI in critical sectors, as well as stimulating innovation and competitiveness in the AI field. Another example is the “legislative proposal on artificial intelligence” [21].

The Meaning of the Expression “AI System”

The authors of the AIR refrained from defining “artificial intelligence” as such. Instead, they defined the concept of an “artificial intelligence system”. Specifically, pursuant to Article 3 (1) of the AIR, an “AI system” means “a machine-based system [22] that is designed to operate with varying levels of autonomy and that may exhibit adaptiveness after deployment and that, for explicit or implicit objectives, infers, from the input it receives, how to generate outputs such as predictions, content, recommendations or decisions that can influence physical or virtual environments” [23]. This definition is reproduced verbatim in Article 2, first sentence of the Council of Europe Framework Convention on Artificial Intelligence, Human Rights, Democracy and the Rule of Law [24].

Article 3 Para. (1) of the Proposal for a Regulation previously provided that an AI system “means software that is developed with one or more of the techniques and approaches listed in Annex I and that, for a given set of human-defined objectives, can generate outputs such as content, predictions, recommendations or decisions influencing the environments with which it interacts” [25].

In ordinary modern Romanian usage, the expression “artificial intelligence” is explained as “a field of computer science that develops technical systems capable of solving complex problems related to human intelligence” [26]. By contrast, the National Strategy defines AI as “a set of systems that display intelligent behaviours and take actions with a certain degree of autonomy”. Art. 2 point 1 of the Draft Law on the responsible use of artificial intelligence also provides a synthetic and suggestive definition. Specifically, AI is “any information system capable of performing cognitive functions [27], such as learning, reasoning and decision-making” [28]. By contrast, the Draft Law on artificial intelligence defines it as “... an advanced way of processing, in the virtual environment [29], a large amount of data, metadata and information by applying predefined algorithms, with the aim of performing, within an optimal time frame, certain anticipatory tasks” [30].

In our view, the definitions of AI provided by the AIR and by the Proposal for a Regulation raise several specific observations.

It can be observed that, in the definition in the AIR, the explicit identification of AI with “software”, that is, with “a set of information necessary for the operation of a computer” [31], was not taken over from the “Proposal for a Regulation”. Even under these conditions, the definition in the AIR refers to “the input data that the machine receives” (that is, in fact, the computer). Explicitly or implicitly, AI is still identified with a “computer program” [32]. We emphasize that a “computer program” is a set of instructions intended to be used with the aid of a computer to obtain certain results [33]. Any computer consists of a visible component called hardware, made up of circuits, devices and equipment components of a computing system (computer or, in the language of the AIR, “machine”), and an invisible part, called software, made up of the totality of programs with which the computing system is equipped (the logical part), whose role is to perform tasks on a computer, phone, tablet, server, etc.

The definition provided by the AIR introduces two new elements: “autonomy” [34] and “adaptiveness” [35] of the system. We note that the National Strategy on AI also refers to “a certain degree of autonomy” of “intelligent components”. However, it cannot be ignored that

“the machine-based system is designed to operate with varying levels of autonomy”. However, system autonomy is not absolute but limited by the levels conceived by the developer and by the objectives pursued. The very notion of a “system” implies subordination IA to a specific purpose for which it was created. In fact, the definition in the AIR expressly refers to the “explicit or implicit objectives” of the system. Obviously, the adaptability of the system after deployment depends on the levels of autonomy for which it was designed to operate and on the intended purpose. The autonomy of the system is limited not only by the “explicit or implicit objectives” for which it was designed, but also by “the input data that it receives”. Only under these conditions of autonomy can the system generate certain outputs (such as predictions, content, recommendations, or decisions).

Since system autonomy depends on its designer and its outputs depend on the input data, the creativity of the system itself is dependent on „human creativity” [36]. As intelligence is a *sine qua non* condition of creativity, it may be asserted that so-called “artificial intelligence” is exclusively a creation of human intelligence [37].

Given the binding legal force of EU regulations in the legal systems of the Member States, the definition of “AI systems” provided by Article 3 of the AIR is mandatory in the Romanian legal system as well. Consequently, Romanian authorities, institutions and citizens are not free to disregard this legal meaning [38].

Conclusions

From the above considerations, it follows that at EU level there is a genuine “normative effervescence” regarding artificial intelligence. The same cannot be said about the Romanian legislative system, where initiatives remain timid, limited in scope and often stagnate in various parliamentary stages. We express the opinion that, from this perspective, the activity of the Romanian Committee for Artificial Intelligence (RC-AI) [39] should be revitalized, whose role is “to support the MCID [40] in exercising its duties as a state authority in the field of research-development, innovation and digitalisation, through proposals regarding the regulation, coordination, monitoring and evaluation of activities related to artificial intelligence”.

Contrary to the objective explicitly expressed in the “Proposal for a Regulation”, namely to clearly define AI, in order to ensure, among other things, “legal certainty”, the definition established by the AIR is sophisticated, with a high potential for diverse interpretations. It remains the task of academic doctrine in the field to substantiate a synthetic definition, devoid of ambiguities, non-interpretative and promoting the idea that “intelligence”, as a *sine qua non* element of “creativity”, is exclusively human.

REFERENCES

- [1] The White Paper is officially identified under code number COM (2020) 65 final – CELEX 52020DC0065.
- [2] The Convention is available at the web address: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://eur-lex.europa.eu/legal-content/RO/TXT/PDF/?uri=CONSIL:ST_12516_2024_INIT (accessed on 1 December 2025) [for some details regarding this Convention, see M. Duțu, *Primul tratat internațional privind inteligența artificială*, available at the web address: <juridice.ro/essentials/7647/primul-tratat-international-privind-ia> (accessed on 1 December 2025)].
- [3] The Council of Europe was established by the “Statute of the Council of Europe”, known as the “Treaty of London of 5 May 1949” [available at the web address: <https://legislatie.just.ro/Public/DetaliiDocument/30114> (accessed on 6 December 2025)]. The main objective of the Council of Europe is to promote unity among

European states [Art. 1 letter (a)]. At present, the following states are members of the Council of Europe: Albania, Andorra, Armenia, Austria, Azerbaijan, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Moldova, Monaco, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, San Marino, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine and the United Kingdom.

- [4] See Art. 36 of the Convention.
- [5] Regulation (EU) 2024/1689 of the European Parliament and of the Council laying down harmonised rules on artificial intelligence was published in the Official Journal of the European Union, Series L of 12 July 2024 (for brevity, hereinafter, within this study, references to this Regulation will be made using the abbreviation “AIR”).
- [6] The Treaty on the Functioning of the European Union (TFEU) was concluded in Maastricht on 7 February 1992, between Belgium, Denmark, Germany, Greece, Spain, France, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Great Britain and Ireland. Subsequently, the following European states acceded to the EU: Bulgaria, Czech Republic, Estonia, Cyprus, Latvia, Lithuania, Hungary, Malta, Austria, Poland, Romania, Slovenia, Slovakia, Finland and Sweden. By contrast, Great Britain and Northern Ireland withdrew from the EU on 31 January 2020. (The consolidated version of the TFEU is published in the Official Journal of the European Union, Series C 202/47 of 7 June 2016).
- [7] Concretely, Art. 113 final sentence of the AIR provides that “this Regulation shall be binding in its entirety and directly applicable in all Member States”.
- [8] The document is available at the web address: <https://eur-lex.europa.eu/legal-content/RO/TXT/HTML/?uri=CELEX:52021PC0206&from=EN> (accessed on 27 November 2025). For brevity, hereinafter, within this study, references to the “Proposal for a Regulation of the European Parliament and of the Council laying down harmonised rules on artificial intelligence (Artificial Intelligence Act) and amending certain Union legislative acts” will be made using the expression “Proposal for a Regulation”.
- [9] The Authority for the Digitalisation of Romania (ADR) put the “Proposal for a Regulation” to public consultation starting on 16 September 2021 [for details, see the web address: <https://www.adr.gov.ro/adr-pune-in-dezbatere-publica-prima-propunere-legislativa-privind-inteligenta-artificiala-formulata-la-nivel-european/> (accessed on 27 November 2025)].
- [10] Art. 6 para. (1) of the AIR establishes the conditions under which a certain AI system presents a high degree of risk.
- [11] In exercising its duties under the AIR, the European Commission (EC) is assisted by a “committee”, pursuant to Art. 98 para. (1) of the AIR. This committee operates under the conditions of Regulation (EU) 182/2011 laying down the rules and general principles concerning mechanisms for control by Member States of the Commission’s exercise of implementing powers (published in the Official Journal of the European Union, Series L 55/13 of 28 February 2011).
- [12] The AIR amended the following directives: Directive 2014/90/EU of the European Parliament and of the Council of 23 July 2014 on marine equipment and repealing Council Directive 96/98/EC (published in the Official Journal of the European Union, Series L 257/146 of 28 August 2014); Directive (EU) 2016/797 of the European Parliament and of the Council of 11 May 2016 on the interoperability of the rail system within the European Union (published in the Official Journal of the European Union, Series L 138/44 of 25 May 2016); Directive (EU) 2020/1828 of the European Parliament and of the Council of 25 November 2020 on representative actions for the protection of the collective interests of consumers and repealing Directive 2009/22/EC (published in the Official Journal of the European Union, Series L 409/1 of 4 December 2020).
- [13] The AIR amended the following regulations: Regulation (EC) No 300/2008 of the European Parliament and of the Council of 11 March 2008 on common rules in the field of civil aviation security and repealing Regulation (EC) No 2320/2002 (published in the Official Journal of the European Union, Series L 97/72 of 9 April 2008); Regulation (EU) No 167/2013 of the European Parliament and of the Council of 5 February 2013 on the approval and market surveillance of agricultural and forestry vehicles (published in the Official Journal of the European Union, Series L 60/1 of 2 March 2013); Regulation (EU) of the European Parliament and of the Council No 168/2013 of 15 January 2013 on the approval and market surveillance of two- or three-wheel vehicles and quadricycles (published in the Official Journal of the European Union, Series L 60/52 of 2 March

- 2013); Regulation (EU) 2018/858 of the European Parliament and of the Council of 30 May 2018 on the approval and market surveillance of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles, amending Regulations (EC) No 715/2007 and (EC) No 595/2009 and repealing Directive 2007/46/EC (published in the Official Journal of the European Union, Series L 151/1 of 14 June 2018); Regulation (EU) 2018/1139 of the European Parliament and of the Council of 4 July 2018 on common rules in the field of civil aviation and establishing a European Union Aviation Safety Agency, and amending Regulations (EC) No 2111/2005, (EC) No 1008/2008, (EU) No 996/2010, (EU) No 376/2014 and Directives 2014/30/EU and 2014/53/EU of the European Parliament and of the Council, and repealing Regulations (EC) No 552/2004 and (EC) No 216/2008 of the European Parliament and of the Council and Council Regulation (EEC) No 3922/91 (published in the Official Journal of the European Union, Series L 212/1 of 22 August 2018); Regulation (EU) 2019/2144 of the European Parliament and of the Council of 27 November 2019 on type-approval requirements for motor vehicles and their trailers, and systems, components and separate technical units intended for such vehicles, as regards their general safety and the protection of vehicle occupants and vulnerable road users, amending Regulation (EU) 2018/858 of the European Parliament and of the Council and repealing Regulations (EC) No 78/2009, (EC) No 79/2009 and (EC) No 661/2009 of the European Parliament and of the Council and Regulations (EC) No 631/2009, (EU) No 406/2010, (EU) No 672/2010, (EU) No 1003/2010, (EU) No 1005/2010, (EU) No 1008/2010, (EU) No 1009/2010, (EU) No 19/2011, (EU) No 109/2011, (EU) No 458/2011, (EU) No 65/2012, (EU) No 130/2012, (EU) No 347/2012, (EU) No 351/2012, (EU) No 1230/2012 and (EU) 2015/166 of the Commission (published in the Official Journal of the European Union, Series L 325/1 of 16 December 2019).
- [14] Annex I of the AIR includes, in Section A, the “list of Union harmonisation legislation” (7 directives and 5 regulations) and, in Section B, the “list of other Union harmonisation legislation” (2 directives and 6 regulations). This results in a total of 9 directives and 11 regulations that must be harmonised with the provisions of the AIR.
- [15] The EU internal market is defined by Art. 26 para. (2) of the TFEU as follows: “the internal market shall comprise an area without internal frontiers in which the free movement of goods, persons, services and capital is ensured in accordance with the provisions of the Treaties”.
- [16] EU values are provided by Art. 2 of the TFEU. Specifically, “the Union is founded on the values of respect for human dignity, freedom, democracy, equality, the rule of law and respect for human rights, including the rights of persons belonging to minorities. These values are common to the Member States in a society characterised by pluralism, non-discrimination, tolerance, justice, solidarity and equality between women and men”.
- [17] The Charter of Fundamental Rights of the European Union was proclaimed by the European Parliament, the European Council and the European Commission in Nice on 7 December 2000 and re-proclaimed in Strasbourg on 12 December 2007.
- [18] See Art. 1 of Government Decision No. 832/2024 (published in the Official Gazette No. 730 of 25 July 2024). The Strategy was elaborated by the Authority for the Digitalisation of Romania (ADR) together with the Technical University of Cluj-Napoca – NSC-AI (“National Strategic Centre for AI”) within a joint ADR+University project. The Strategy is published in the Official Gazette No. 730 bis of 25 July 2024, as Annex No. 1 to Government Decision No. 832/2024.
- [19] Senate Decision No. 110/2021 was published in the Official Gazette No. 902 of 21 September 2021. According to Art. 1, “the Senate of Romania finds that the Proposal for a Regulation of the European Parliament and of the Council laying down harmonised rules on artificial intelligence (Artificial Intelligence Act) and amending certain Union legislative acts – COM (2021) 206 final respects the principles of subsidiarity and proportionality”. According to Art. 2, “the Senate of Romania considers that: the proposal presents a balanced and proportionate horizontal approach to the regulation of artificial intelligence (AI), which is limited to the minimum requirements necessary to address risks and issues related to AI, without unjustifiably limiting or hindering technological development or otherwise disproportionately increasing the cost of placing AI solutions on the market [letter (a)]; the proposal establishes a robust and flexible legal framework” [letter (b)].
- [20] The proposal was initiated by a group of senators and deputies and was registered with the Senate under No. PL140/2025 and with the Chamber of Deputies under No. PLx184/2025 [for details, see the web address: https://www.senat.ro/legis/lista.aspx?nr_cls=L140&an_cls=2025 (accessed on 3 December 2025)]. PLx

- 336/2024 is available at the web address: https://www.cdep.ro/pls/proiecte/upl_pck2015.proiect?idp=21650&prm=1 (accessed on 5 December 2025). The first chamber seized was the Senate, which rejected the legislative proposal. The project is currently before the Chamber of Deputies, at the stage “report submitted”, to be placed on the agenda [see the web address: https://www.cdep.ro/pls/proiecte/upl_pck2015.lista?cam=2 (accessed on 6 December 2025)]. The Chamber of Deputies is the “decisional chamber”. Therefore, this project cannot be tacitly adopted [see Art. 75 para. (2) of the Constitution].
- [21] We note the debatable definition of the “AI system” through “system” or, in other words, “by itself”. It is unanimously accepted that the definition of a notion must determine the attributes proper to that notion [see Dex online, available at the web address: <https://dexonline.ro/definitie/defini%C8%9Bie> (accessed on 29 December 2025)]. We specify that the term “system” has the meaning of “a set of elements (principles, rules, forces, etc.) dependent on each other and forming an organised whole, which...”, among other things, “... makes a practical activity function according to the pursued purpose” [see Dex online, available at the web address: <https://dexonline.ro/definitie/sistem> (accessed on 29 December 2025)].
- [22] We note that the White Paper on Artificial Intelligence also provides a definition of AI. Thus, in a synthetic manner, it provides that “AI is a set of technologies that combine data, algorithms and computing power”.
- [23] The second sentence provides that “different artificial intelligence systems vary in their levels of autonomy and capacity to adapt after deployment”.
- [24] Recital 6 of the “Proposal for a Regulation” provided that “the notion of AI system should be clearly defined to ensure legal certainty, while at the same time providing the necessary flexibility to account for future technological developments” and that “the definition should be based on the essential functional characteristics of software, in particular the capacity, for a given set of human-defined objectives, to generate outputs such as content, predictions, recommendations or decisions influencing the environment with which the system interacts, whether physical or digital”.
- [25] See the Explanatory Dictionary of the Romanian Language (DEX), published under the auspices of the Romanian Academy, Institute of Linguistics “Iorgu Iordan”, 2nd ed., revised and supplemented, Univers Enciclopedic Publishing House, Bucharest, 2016, p. 562.
- [26] The term “cognitive” means something “relating to the capacities and mechanisms of learning and accessing knowledge, to cognition” (see DEX, p. 222).
- [27] Artificial intelligence is also defined in some renowned works. For example, the English Oxford Dictionary considers artificial intelligence to be “the theory and development of computer systems able to perform tasks that normally require human intelligence, such as visual perception, speech recognition, decision-making and translation between languages” [see L. M. Stănilă, *Inteligența artificială. Dreptul penal și sistemul de justiție penală. Amintiri despre viitor*, Universul Juridic Publishing House, Bucharest, 2020, p. 35 apud O. Predescu, O.-R. Predescu, *Inteligența artificială azi. O perspectivă a dreptului, a dreptului omului, a eticii și nu numai*, Universul Juridic Publishing House, Bucharest, 2023, p. 73]. Encyclopaedia Britannica defines artificial intelligence as “the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings” [see O. Predescu, O.-R. Predescu, op. cit., p. 73].
- [28] Within the draft law, the “virtual environment” is defined as “the totality of characteristics given by a non-physical environment, where a large amount of data is stored and which can be accessed through conventional electronic equipment or quantum computers”. By contrast, the “physical environment” is considered “the totality of characteristics given by the surrounding environment, without limiting ourselves to them, characterised by extent, both vertically and horizontally, surface, obstacles and the time required to reach two points located at a distance from one another”.
- [29] Within this draft law, artificial intelligence is structured into three categories: Narrow Artificial Intelligence (NAI), through which a limited series of activities and operations are carried out; General Artificial Intelligence (GAI), through which the same activities and operations that a human person can perform are carried out; Super Artificial Intelligence (SAI), which, through the modalities and characteristics of the operations performed, surpasses human intelligence.

- [30] See Dex online, available at the web address: <https://dexonline.ro/definitie/software> (accessed on 30 November 2025).
- [31] In Romania, computer programs are included in the category of “literary works” and are legally protected by copyright, according to Art. 7 letter (a) et seq. of Law No. 8/1996 on copyright and related rights (published in the Official Gazette No. 60 of 26 March 1996 and republished in No. 489 of 14 June 2018). At European level, Council Directive 91/250/EEC on the legal protection of computer programs was adopted (published in the Official Journal of the European Union, Series L 122/42 of 17 May 1991). Directive 91/250/EEC was transposed ad litteram into Romanian domestic law by Law No. 8/1996, pursuant to Art. 209 letter (a). Interestingly, both the Directive and Law No. 8/1996 do not define the computer program. In the preparatory works for the elaboration of the Directive, the Council of the European Communities defined the computer program as “a set of instructions intended to enable the performance of functions by an information processing system called a computer”.
- [32] The 1978 Model Law on Copyright of the World Intellectual Property Organization [Model Law on Copyright (1978), elaborated by WIPO (World Intellectual Property Organization) and UNESCO (United Nations Educational, Scientific and Cultural Organization) to serve as a model for states modernising their copyright legislation], stated that the computer program is “a set of instructions which, once transposed onto a medium readable by a machine capable of processing information, can indicate, execute or allow the obtaining of information, a task or a result”. The similarity between the meaning provided by the Council of the European Communities and that provided by the WIPO Model Law for the computer program is noticeable (see T. Bodoaşcă, L.-I. Tarnu, A. Bogdan, *Dreptul proprietăţii intelectuale*, 6th ed., revised and supplemented, Universul Juridic Publishing House, Bucharest, 2024, p. 216).
- [33] *Idem*.
- [34] Autonomy is the state of someone being autonomous, that is, not depending on anyone [see DEX, p. 85].
- [35] Adaptability is the quality of being adaptable, that is, of transforming in order to meet certain requirements (see DEX, p. 13).
- [36] In doctrine, it has been unquestionably appreciated that “creativity is a specifically human attribute” (see T. Bodoaşcă, L.-I. Tarnu, A.-V. Bogdan, op. cit., pp. 21–22).
- [37] Intelligence consists in “the capacity to understand easily and well, to grasp what is essential, to solve new situations or problems based on previously accumulated experience” (see DEX, p. 562).
- [38] See Art. 148 para. (2) of the Constitution (for some details regarding the relationship between domestic law and European Union law, see E.-S. Tănăsescu, *Integrarea în Uniunea Europeană, în Constituţia României. Comentariu pe articole*, by I. Muraru, E.-S. Tănăsescu (coordinators) and collective, 3rd ed., revised and supplemented, C.H. Beck Publishing House, Bucharest, 2022, p. 1349 et seq.).
- [39] RC-AI was established and operates pursuant to Order No. 20484/2023 of the Minister of Research, Innovation and Digitalisation (published in the Official Gazette No. 382 of 4 May 2023).
- [40] MCID is the abbreviation of “Ministry of Research, Innovation and Digitalisation”. At present, the subordination of the RC-AI is ambiguous, since MCID no longer appears in the list of ministries provided by Parliamentary Decision No. 25/2025 granting confidence to the Government (published in the Official Gazette No. 580 of 23 June 2025).

ETHICS IN THE AGE OF ALGORITHMS: RESPONSIBLE USE OF GENERATIVE AI IN ACADEMIC EDUCATION AND RESEARCH

Prof. univ. Brîndușa GOREA Ph.D.

*"Dimitrie Cantemir" University of Târgu Mureș, Târgu Mureș, Faculty of Law, Romania
Corresponding author: Brîndușa GOREA: brindusagorea@yahoo.com*

Abstract

The article explores the ethical, legal, and institutional implications of the growing presence of generative artificial intelligence in higher education and scientific research. It aims to identify the key principles that ensure the responsible and transparent use of these technologies within universities, based on the analysis of recent international and European policy documents. The study adopts a comparative and analytical approach, examining how the main regulatory instruments - such as ethical codes, recommendations, and guidelines - shape the new research culture in the age of intelligent systems. Special attention is given to the second version of the European Commission's Guidelines on the Responsible Use of Generative AI in Research (April 2025), which transforms abstract ethical concepts into practical responsibilities for researchers and institutions. The conclusions emphasize the necessity of integrating AI literacy and ethical reflection into academic training, promoting human oversight, transparency, and accountability as fundamental conditions of scientific integrity. The paper argues that the future of academia depends not on resisting technological innovation but on guiding it ethically, ensuring that artificial intelligence remains a tool serving human creativity and moral responsibility.

Keywords: ethics, generative artificial intelligence, research integrity, higher legal education, transparency, human oversight

Introduction

Artificial intelligence has become, in recent years, an increasingly visible presence in our daily lives. It influences the way we live, work, learn and do research. At the same time, science has progressed rapidly in the field of automated data processing, supported by the massive increase in the volume of information, increasing computing power, and advanced machine learning techniques. All of this has contributed to an unprecedented acceleration of the evolution of AI.

An important step was the emergence of basic models - systems trained on huge sets of unlabeled data, such as ChatGPT-5, GPT-5, Claude Opus 4.1, Gemini 2.5 Pro, Qwen 3 Max, Grok 4, LLaMA 3.1 or DeepSeek. These models have made it possible to develop general-purpose artificial intelligence capable of performing advanced reasoning, language processing, and contextual understanding tasks.

In this context, generative artificial intelligence has gained a central role. It can create original content - text, code, images, music, voice, or video - based on instructions provided by

the user. The results obtained are often so complex and coherent that it becomes difficult to differentiate them from human creations. Moreover, strict regulation of this field seems like an impossible mission, given the constant changes that makes it a moving target [2, 3, 4, 5].

However, it is essential that these systems are used with discernment. Human intervention and critical judgment remain fundamental, especially in legal research and legal education, where correct and contextual interpretation is crucial.

Responsibility has long been recognized as a cornerstone of legal education. Law graduates should possess a strong awareness of their social role and be equipped to act not only as competent legal professionals but also as ethically responsible members of society. [6, 7, 8]

It's not just about technology. It's about how we choose to use it, how we decide what's relevant, and how we contextualize the information [5]. Without this step, even the most sophisticated models remain just tools, no matter how impressive they are.

For the future, a significant expansion of AI use is anticipated across multiple sectors of social and economic life, including education, where the adoption of intelligent tutoring systems and other AI technologies is expected to increase, assisting teachers both in the classroom and at home, as well as supporting learning based on virtual reality applications [4, 5].

The proliferation of generative artificial intelligence tools and AI-assisted technologies creates new opportunities for academic research, but also significant risks to scientific integrity: assisted plagiarism, data fabrication/alteration, loss of methodological traceability, and possible ambiguities or even violations of copyright and intellectual property. A relevant example is the integration of AI into English language learning, where intelligent technologies can support the personalization and efficiency of the educational process [11].

Despite these challenges, AI has the potential to transform education, making it more accessible and personalized, if implemented correctly. The future of education will depend on how these challenges are addressed and how AI-based educational technologies evolve [13].

In this article, we aim to inventory the main normative acts, codes of ethics and recommendations formulated at European and international level, which are related to the responsible use of generative artificial intelligence in education and academic research.

There are two main reasons behind our research objective.

On the one hand, we are trying to detect in what way the ethical considerations, which have been an essential component in the consolidation of a united Europe, changed under the impact of the changes that Artificial Intelligence has brought to every aspect of our individual and common lives.

On the other hand, we aim to extract from the most recent regulations and recommendations a core of principles for the ethical use of generative artificial intelligence in universities, both in terms of teaching and research activity of teachers and students. The conclusions of this study can also constitute the basis for the drafting of a Practical Guide to the ethical use of Artificial Intelligence in academic activity, especially within law faculties.

Principles and Moral Values of University Ethics in International Documents

Technological evolution has progressed from the use of rudimentary computers, which were limited to basic data processing, text editing, and entertainment, to complex information systems that have quickly raised concerns regarding the need for appropriate regulation. This transformation has been highlighted both in the context of the digital formation of companies through European directives [12] and in analyses of the impact of digitalization on European

competition law [9]. Moreover, the process of digitizing the judicial system highlights how digital technologies and artificial intelligence influence not only legal practice, but also education and research in the field, emphasizing the importance of ethical and responsible approaches [10].

In parallel with these technological advancements and regulatory concerns, the principles and moral values of university ethics have been and continue to be a constant concern of various European and international bodies interested in ensuring quality standards in higher education and harmonizing national laws and practices in this field.

Documents such as:

- **the Bologna Declaration** (1999)
[https://ehea.info/Upload/document/ministerial_declarations/1999_Bologna_Declaration_English_553028.pdf (accessed on 29.10.2025)],
- **the UNESCO Recommendations Concerning the Status of Higher-Education Teaching Personnel** (1997) [<https://www.unesco.org/en/legal-affairs/recommendation-concerning-status-higher-education-teaching-personnel?hub=66722> (accessed on 29.10.2025)],
- **the Code of Ethics of the European Network for Academic Integrity** - ENAI (2022)
<https://www.academicintegrity.eu/wp/glossary/code-of-ethics/> (accessed on 29.10.2025)],
- **the European Charter for Researchers and the Code of Conduct for the Recruitment of Researchers** (2005)
[<https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32005H0251&qid=1716377573815> (accessed on 29.10.2025)] or
- **the Singapore Declaration on Integrity in Scientific Research** (2010)
<https://www.wcrif.org/guidance/singapore-statement> (accessed on 29.10.2025)]
- to give just a few examples - set out the basic principles of research integrity, provide recommendations on the prevention of plagiarism, fraud and other deviations from the norms of academic integrity and support the adoption of rigorous codes of ethics.

Synthetically speaking, the four general principles of research integrity, which emerge unequivocally from the aforementioned documents, are: (1) honesty; (2) liability; (3) transparency and (4) mutual respect.

However, the recent experience of how AI has invaded the field of education and academic research (and continues to impose itself as a reality that we cannot ignore) forces us to constantly reassess how we can verify compliance with the ethics of academic research. International bodies such as UNESCO, the European Commission, the Parliament and the Council of the EU or the OECD have adopted, in the last 2-3 years, a series of documents relevant to university ethics and scientific research, with a focus on the relationship between generative artificial intelligence (generative AI) and academic integrity/research ethics, which we will present below.

EU Artificial Intelligence Act (Regulation (EU) 2024/1689)

Adopted by the EU Parliament and Council in June 2024
<https://www.europarl.europa.eu/topics/en/article/20230601STO93804/eu-ai-act-first-regulation-on-artificial-intelligence> (accessed on 29.10.2025)], it is the first comprehensive

legal framework for AI. Although it does not contain direct references to university ethics, we consider it necessary to mention it, because it imposes the classification of AI applications according to the level of risk, requirements for transparency, explainability and human control, as well as obligations for entities that develop or use AI in research activities. The EU AI Act is relevant for academia and for universities and research institutes to become 'AI operators' within the meaning of the law, with specific responsibilities.

Council of Europe – Framework Convention on Artificial Intelligence, Human Rights, Democracy and the Rule of Law (2024)

Adopted in Strasbourg in September 2024 [<https://rm.coe.int/1680afae3c> (accessed on 29.10.2025)], it is the first international convention on AI, having also been signed by the United States of America [<https://www.state.gov/bureau-of-democracy-human-rights-and-labor/the-council-of-europes-framework-convention-on-artificial-intelligence-and-human-rights-democracy-and-the-rule-of-law> (accessed on 29.10.2025)]. This framework convention enshrines principles of transparency, accountability and the protection of fundamental rights, including in research and education. It provides for the obligation of member states (including Romania) to implement ethical policies for the use of AI in governance, but also in education and research.

OECD AI Principles (adopted in 2019, updated in 2024)

The principles adopted in 2019 by OECD and G20 member countries were updated in May 2024 [<https://oecd.ai/en/ai-principles> (accessed on 29.10.2025)] and reaffirm five pillars: (1) AI beneficial to people and planet; (2) Respect for human rights and the rule of law; (3) Transparency and explainability; (4) Accountability and accountability and (5) Robustness, security and safety.

These principles are relevant to the field of academic research, as they guide the assessment of the ethical impact of generative AI on data and the scientific process.

UNESCO Recommendation on the Ethics of Artificial Intelligence (2021, implementation 2023–2025)

Although adopted 4 years ago, in 2021 [<https://www.unesco.org/en/articles/recommendation-ethics-artificial-intelligence> (accessed on 29.10.2025)], this document is still in the process of implementation, including in Romania.

It includes specific requirements for education and research systems, such as ethical training in the use of AI, respect for diversity and inclusion, or ensuring transparency of algorithms used in research and education.

European Code of Conduct for Research Integrity (ALLEA 2023)

The European Federation of Academies of Sciences and Arts, known by the acronym ALLEA - All European Academies, is a non-governmental organization that was established in 1994 and represents 60 academies from 40 countries, members and non-members of the European Union, including the Romanian Academy.

ALLEA's vision is to "support science not only for its contribution to solving societal challenges, but also for its intrinsic value in human culture and intellectual development, while

recognizing the essential role of scientific evidence in maintaining social cohesion and progress". [<https://allea.org/allea-in-brief/> (accessed on 11.10.2025)].

The European Code of Conduct for Research Integrity [The European Code of Conduct for Research Integrity is available at <https://allea.org/wp-content/uploads/2023/06/European-Code-of-Conduct-Revised-Edition-2023.pdf> (accessed on 11.10.2025)], considered to be the European reference standard in the field, was initially developed in 2011 and revised in 2017, then in 2023.

The interpretation of the values and principles that govern research can be influenced by social, political or technological developments, as well as by changes in the research environment, the document shows.

Successive revisions are motivated by the desire for this Code to remain "a living document", "fit for purpose and relevant to all disciplines and emerging fields of research", taking into account scientific and technological developments and recent research practices [The use of social media, access to "Open Science" resources, the need to protect personal data, etc.]. Such changes reflect, in the authors' opinion, *"a new awareness of the importance of research culture"* in supporting research integrity and applying good research practices".

Also in our opinion, more than just rules and regulations are needed to cope with the current technological assault. These seem like flimsy sandbanks in the face of a tsunami now that generative AI has become a part of the lives of all of us, including students and teachers/researchers. A culture of integrity in research is needed, and the first step for this is education (digital, but also moral/ethical).

It is interesting to note that the revised 2023 edition hardly refers to AI, as an example of good practice in research procedures ("Researchers report their results and methods, including the use of external services or artificial intelligence and automated tools, in a way that is compatible with the accepted norms of the discipline and that facilitates verification.") or as an example of deviation from research conduct and other unacceptable practices ("Hiding the use of artificial intelligence or automated tools in content creation or publication writing."). Here, just two years later, the need to regulate the use of AI in academic research has grown exponentially and no longer refers only to researchers, in the traditional sense of the term, but also to how students can use new technologies, in a way that remains ethical and useful to their educational needs.

The European Code of Conduct for Research Integrity provides in its Preamble a definition of research in all scientific and academic fields, understood as an approach of the countless actors on the academic, industrial scene, etc.: "Research is the search for knowledge obtained through systematic study, reflection, observation and experimentation. Although different disciplines may use distinct methods, they all share the motivation to enhance our understanding of ourselves and the world we live in."

The European Code of Conduct for Research Integrity developed by ALLEA is considered a reference standard for research ethics and is taken as a model for numerous codes of conduct in research, as the good practices it proposes are based on the basic principles of research integrity:

1. **Reliability** in research quality assurance, reflected in design, methodology, analysis and use of resources.
2. **Honesty** in developing, conducting, evaluating, reporting and communicating research in a transparent, fair, complete and impartial manner.
3. **Respect** for colleagues, research participants, research subjects, society, ecosystems, cultural heritage and the environment.

4. Responsibility for research, from idea to publication – for its management and organization, for training, supervision and mentoring, as well as for its wider impact on society.

Here are just a few examples of good practices contained in the "ALLEA Code", which we consider relevant for the purpose of our study:

1. Research institutions and organizations shall develop appropriate and appropriate training programmes in research ethics and integrity, to ensure that all those involved are aware of the relevant codes and regulations and acquire the necessary skills to apply them in their research work.
2. Researchers, throughout their careers – from those at the beginning of their journey to those with extensive experience – attend training courses in research ethics and integrity.
3. Researchers, institutions and research organizations shall ensure that access to data is as open as possible, as restricted as necessary and, where required, in line with the FAIR (Findable, Accessible, Interoperable and Reusable) principles for data management.
4. Researchers, research institutions and organizations are transparent about how they access and obtain permission to use data, metadata, protocols, code, software and other research materials.
5. Researchers, institutions, and research organizations recognize data, metadata, protocols, code, software, and other research materials as legitimate and citable products of research activity.
6. Researchers, institutions and research organizations shall ensure that any contracts or agreements relating to research results include fair and fair provisions on the management of their use, ownership and protection, in accordance with intellectual property rights.

Failure to comply with good practices in research is a violation of professional integrity and responsibility. This is likely to negatively affect research processes, degrade relationships between researchers, undermine trust and credibility of research, waste resources, and may expose research participants and subjects, users, society, or the environment to unnecessary risks.

Deviations from good conduct in research are traditionally defined as fabrication, falsification or plagiarism (known by the acronym FFP) in the design, conduct or evaluation of research, or in the reporting of research results. According to the ALLEA Code, "fabrication" consists of inventing data or results and recording them as if they were real. "Falsification" involves the manipulation of research materials, equipment, images or processes, or the alteration, omission or deletion of data or results, without justification. Finally, "plagiarism" means the use of other people's work or ideas without giving due credit to the original source.

Other examples of unacceptable research practices mentioned in the European Code of Conduct for Research Integrity developed by ALLEA include, but are not limited to:

1. Hiding the use of artificial intelligence or automated tools in content creation or publication writing.
2. Fragmentation of research results with the explicit aim of increasing the number of scientific publications ("salami-type publications").
3. Selective or inaccurate citation.
4. Unnecessary expansion of a study's bibliography to please editors, reviewers, or peers, or to manipulate bibliographic data.

5. Republishing substantial parts of your own previous publications, including translations, without properly mentioning or citing the original source ("self-plagiarism").
6. Establishing, endorsing, or deliberately using journals, publishers, events, or services that undermine the quality of research ("predatory journals/conferences/factories"). ('predatory' journals or conferences and paper mills).
7. Participation in cartels of reviewers and authors who agree to evaluate each other's publications.

In their most serious forms, unacceptable practices must, of course, be sanctioned, but first every effort must be made to prevent, deter and stop such behavior, through training, supervision, mentoring and the development of an ethical research environment.

As a conclusion on the 2023 ALLEA Code of Conduct, we can consider that, although already outdated in some respects, it remains a reference standard for research integrity and provides the general framework in which issues of copyright, data fabrication, verifiability and declaration of the use of automated tools, such as generative AI, must be analyzed.

Guidelines on the Responsible Use of Generative AI in Research (European Commission, 2nd version, April 2025)

In the context of the accelerated transformations brought about by the integration of generative artificial intelligence into scientific work, the European Commission, in collaboration with the European Research Area Forum (ERA Forum), has developed the document "Guidelines on the responsible use of generative artificial intelligence in research" [Living guidelines on the Responsible Use of Generative AI in Research, available online on https://research-and-innovation.ec.europa.eu/document/download/2b6cf7e5-36ac-41cb-aab5-0d32050143dc_en?filename=ec_rtd_ai-guidelines.pdf (accessed on 11.10.2025)]. These guidelines, originally published in March 2024 and updated in the second edition in April 2025, provide a common framework at European level for the ethical, transparent and responsible use of AI technologies in research. The preparation of the document was the result of an extensive consultative process within the ERA Forum, aimed at ensuring the coherence, relevance and applicability of the recommendations across Member States and research areas, thereby strengthening scientific integrity and public trust in AI-assisted research.

The 2025 revision of the European Commission's *Guidelines on the Responsible Use of Generative AI in Research* reflects a clear attempt to move from broad ethical recommendations to more actionable principles. Unlike the initial 2024 version, which mainly outlined the values and general expectations regarding the use of AI in research, the second version takes a more practical and institutional perspective. It addresses specific obligations for researchers, universities, and funding organizations and includes explicit references to the challenges created by generative AI systems capable of producing scientific text, data, or even synthetic experimental results.

The document is structured around three complementary dimensions: (a) **responsibility and accountability** in AI-assisted research, (b) **transparency and traceability** in documenting how AI tools are used in research workflows, and (c) **education and institutional governance** aimed at ensuring a culture of ethical AI use within the European Research Area. This multidimensional approach shows that the Commission understands responsible AI cannot rely

solely on technical standards or individual good will. It also requires an institutional framework that promotes awareness, documentation, and supervision.

A key element introduced in the 2025 edition is the distinction between *AI-assisted* and *AI-generated* research outcomes. While the first refers to the legitimate use of AI as an instrument for analysis, linguistic assistance, or simulation - activities that support but do not replace human reasoning - the second category raises deeper concerns about authorship, intellectual property, and the verification of scientific results. The guidelines therefore recommend that any use of generative AI in producing text, figures, or data be explicitly disclosed in research outputs, with clear indication of the purpose and extent of AI involvement. This recommendation aligns with the principles of the European Code of Conduct for Research Integrity (ALLEA, 2023), which also emphasized transparency and the need to disclose the use of automated tools.

Another innovation in the 2025 version is the emphasis on **human oversight**. The document repeatedly stresses that human researchers must remain “in control” of both the methodology and interpretation of results. Generative AI may support reasoning and creativity, but it cannot replace the human capacity for critical analysis, contextual judgment, and ethical evaluation. In this sense, the guidelines establish a subtle but significant distinction between automation and autonomy: automation of repetitive or technical tasks is acceptable and even encouraged, but delegating autonomy to AI systems in making scientific or ethical decisions is not.

Equally important is the section dedicated to **data governance** and the prevention of “synthetic data misuse.” The Commission warns that models trained on low-quality or biased datasets can reproduce and amplify distortions, leading to unreliable or even discriminatory research outcomes. For this reason, researchers are urged to maintain complete documentation of datasets, prompts, and AI-generated materials used during the research process. This level of documentation - often referred to as *AI provenance tracking* - is meant to ensure reproducibility and accountability, two pillars of scientific integrity that risk erosion in the age of generative models. These recommendations are particularly relevant in fields that rely heavily on data-driven analysis, such as social sciences or law.

The document also draws attention to the **educational dimension** of responsible AI use. They call for universities and research institutions to integrate ethics and digital literacy into curricula at all levels of academic formation. The document explicitly mentions that understanding AI-generated content, biases, and limitations is now part of a researcher’s professional competence. As such, institutions are encouraged to establish internal policies on AI use, including clear procedures for disclosure, supervision, and assessment of AI-generated material in theses, publications, and research proposals. This institutionalization of ethical awareness marks an important shift: the responsibility for integrity in AI-assisted research no longer lies solely with the individual, but also with the educational and research organizations that shape scientific culture.

A particularly relevant section for the academic community is the recommendation to include “AI contribution statements” in research publications. Similar to funding or conflict-of-interest disclosures, these statements should describe how and to what extent AI tools were used in the conception, writing, or analysis stages of the work. The purpose is not to discourage AI usage, but to preserve trust in the authenticity and verifiability of scholarly outputs. Such a measure resonates with current editorial trends among major scientific publishers, which already request authors to indicate the use of large language models or other generative tools during manuscript preparation.

Beyond these technical and procedural recommendations, the guidelines also adopt a **philosophical stance**: they reaffirm the central role of human creativity and ethical reasoning as the foundation of scientific progress. In a concise but impactful paragraph, the 2025 edition states that “generative artificial intelligence must augment, not replace, the cognitive and ethical autonomy of the researcher.” This formulation elegantly captures the spirit of the document: technology should expand the possibilities of inquiry, not diminish the intellectual responsibility of the human agent.

From a broader perspective, the Guidelines are consistent with other European and international initiatives. Their spirit converges with the OECD AI Principles and the UNESCO Recommendation on the Ethics of AI, both of which underline human-centered and rights-based approaches to artificial intelligence. However, the European Commission’s text goes further in operationalizing these principles specifically for the research domain. It provides examples of acceptable practices, such as using AI for statistical modeling or linguistic editing, and contrasts them with risky or unacceptable uses - such as generating entire research papers, fabricating references, or producing synthetic experimental data without disclosure.

In this respect, the Guidelines can be seen as a bridge between legal frameworks (like the EU Artificial Intelligence Act) and ethical codes (like the ALLEA Code or the Singapore Statement). While the AI Act focuses on compliance and risk classification, and ethical codes emphasize values, the 2025 Guidelines occupy an intermediary space: they translate principles into institutional responsibilities. They encourage universities to establish AI ethics committees, implement internal monitoring mechanisms, and provide continuous training for researchers and students. This “middle layer” of governance is precisely what many institutions were missing when faced with the sudden rise of generative AI tools in 2023–2024.

Moreover, the Guidelines introduce the concept of “**collective responsibility**” in research integrity. This notion implies that ethical AI use is not merely an individual moral choice but a shared duty involving peers, mentors, institutions, and funding bodies. Each actor has a role: researchers must disclose and verify, institutions must educate and supervise, and funders must require compliance with transparency standards. This holistic perspective reinforces the idea that ethics is not merely a bureaucratic formality, but an essential condition for credible and socially responsible research.

For faculties of law and social sciences, these recommendations carry particular significance. Legal research, by its interpretative nature, is vulnerable to oversimplifications or distortions introduced by generative models trained on incomplete or biased legal data. The 2025 Guidelines highlight this risk and urge researchers to treat AI outputs as *secondary sources*, not as authoritative interpretations. This is especially relevant for law students who increasingly use AI tools to draft analyses, case summaries, or even legal opinions. According to the European Commission’s approach, transparency about such assistance is not only ethical but necessary for preserving academic integrity.

In conclusion, the *Guidelines on the Responsible Use of Generative AI in Research (2025)* represent a timely and balanced effort to harmonize technological innovation with ethical responsibility. By translating abstract principles into operational measures, the document strengthens the European commitment to trustworthy and human-centered science. It acknowledges both the inevitability and the manageability of generative AI in academic life, suggesting that the solution lies not in restriction, but in education, supervision, and shared responsibility. The integration of these recommendations into university policies - particularly in disciplines such as law, where interpretation and authorship remain central - will be decisive in shaping a culture of ethical and transparent research in the age of intelligent machines.

Towards Possible Guidelines for the Use of Artificial Intelligence by Law Students

The rapid integration of generative artificial intelligence into higher education makes it increasingly necessary to reflect on its ethical and pedagogical implications within legal education.

Faculties of law, traditionally grounded in reasoning, interpretation, and argumentation, now face the challenge of reconciling technological innovation with the values of academic integrity and professional responsibility. This tension is particularly visible in Eastern European contexts, where legal education systems, as noted by Belova and Georgieva [1], continue to evolve under the combined influence of globalization, digitalization, and European legal integration.

In this context, the development of guidelines for the responsible use of AI by law students should be understood not as a restrictive measure, but as a framework for cultivating discernment and ethical judgment in the digital era.

Any future code of conduct for AI use in legal education should be built upon three foundational principles: responsibility, transparency, and integrity. Responsibility entails that students remain intellectually and ethically accountable for the content they produce, regardless of the tools employed. Generative AI can assist in learning, drafting, or linguistic correction, yet it can never replace the student's analytical reasoning or critical evaluation of legal sources. Transparency implies that any use of AI must be disclosed openly and honestly, with explicit reference to the tool, its purpose, and the extent of its contribution. Integrity, finally, presupposes that all AI-assisted work respects the standards of originality, citation, and confidentiality required in the legal profession.

In Law, these principles acquire a particular depth. The use of AI to summarize cases, interpret legislation, or propose arguments must always be accompanied by verification against authoritative sources. Legal education cannot afford to rely on machine-generated generalizations or unverified outputs, since the authority of legal interpretation rests upon human responsibility. Similarly, students should be cautioned against uploading confidential data - such as case materials or personal information - into public AI systems, as such acts may infringe both ethical and legal norms. The same prudence should guide the use of automatic translations of legal texts, which may assist comprehension but must never substitute for official or professionally reviewed versions.

Possible guidelines for law students should therefore encourage the constructive and transparent use of AI, integrated into learning processes as an aid to understanding rather than as a substitute for thought. They should clarify what forms of assistance are acceptable (for example, drafting structures, linguistic revisions, or initial summaries) and what constitutes a breach of integrity (for instance, submitting AI-generated content as one's own or fabricating citations). Ultimately, such recommendations aim to strengthen the culture of academic honesty and the ethical identity of future jurists. The goal is not to exclude technology from the study of law, but to educate students to use it wisely, critically, and with full awareness of their moral and professional responsibilities.

Conclusions

The accelerated emergence of generative artificial intelligence has profoundly transformed the landscape of education and research, challenging the very foundations of how knowledge is produced, validated, and transmitted. The documents analyzed throughout this paper – from

the *European Code of Conduct for Research Integrity (ALLEA, 2023)* to the *UNESCO Recommendation on the Ethics of AI (2021–2025)* and the *Guidelines on the Responsible Use of Generative AI in Research (European Commission, 2025)* – converge toward a shared understanding: technology, no matter how advanced, must remain subordinated to human values and ethical principles.

The central message that arises from these texts is the need to balance innovation with responsibility. Generative AI offers researchers and students unprecedented opportunities for creativity, efficiency, and access to knowledge. Yet these benefits can easily be undermined if the tools are used without transparency, critical judgment, or a clear awareness of their limitations. Ethical reasoning, intellectual honesty, and methodological rigor remain the pillars that distinguish authentic scientific inquiry from mere technological production.

The European framework has evolved remarkably fast in response to the disruptions caused by AI. While the *EU Artificial Intelligence Act (2024)* provides the legal architecture for risk management and accountability, the *2025 Guidelines* complement it with a cultural and institutional dimension, fostering a shared sense of responsibility among researchers, institutions, and society. Together, these instruments aim to preserve trust in science and to protect the integrity of the research process at a time when the boundaries between human and machine authorship are increasingly blurred.

For universities, the challenge is now both pedagogical and ethical. Academic institutions must integrate the responsible use of AI into curricula, teaching not only technical competence but also moral discernment. Faculties of law, in particular, have a duty to cultivate a generation of jurists capable of understanding the implications of algorithmic reasoning for justice, human rights, and democracy. Ethical literacy in AI should become as essential as digital literacy itself.

In this broader reflection, legal education emerges as a particularly relevant field for implementing the principles discussed throughout this study. The proposal for future guidelines on the responsible use of AI by law students illustrates how theoretical ethics can evolve into concrete academic practice. Such guidelines would not only protect the integrity of legal training but also nurture a professional ethos grounded in critical thinking, transparency, and social responsibility. By articulating clear expectations and boundaries for AI-assisted learning, law faculties can transform technological innovation into an opportunity to reinforce the ethical dimension of legal education itself.

Ultimately, the debate on the use of generative AI in academia is not about prohibiting technology, but about redefining the conditions of trust, authorship, and accountability in the digital age. The responsible use of AI does not diminish human creativity – it enhances it, provided that human oversight and critical thinking remain central. The future of academic research will depend not on our ability to resist technological change, but on our capacity to guide it ethically, transforming artificial intelligence from a potential threat into a catalyst for a more reflective, transparent, and human-centered science.

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THE "EFORMS" IN PUBLIC PROCUREMENT

Prof. habil. Emilia Lucia CĂȚANĂ, Ph.D.

"Dimitrie Cantemir" University of Târgu Mureș, Târgu Mureș, Faculty of Law, Romania
Corresponding author: Emilia Lucia CĂȚANĂ: luciacatana@yahoo.fr

Abstract

On 23 September 2019, the European Commission adopted the Implementing Regulation (EU) 1780 establishing standard forms for the publication of notices in the field of public procurement, known as the eForms regulation. This regulation implements the European directives on public procurement remedies no. 89/665/EEC, 92/13/EEC and 2009/81/EC respectively public procurement directives no. 2014/23/EU, 2014/24/EU and 2014/25/EU. In this context, the study analyzes the legal nature and implications of the eForms directive, respectively makes a theoretical analysis of eForms in the context of the new technologies' development in public procurement.

Keywords: eForms, implementing regulation, standard forms, public procurement, automated decision-making, new technologies.

Introduction

Automated decision-making is a reality in the public procurement law. The public procurement automation involves the new technologies development in public procurement. Thus, the administrative decision-makers and the public servants involved, as much as the privat operators, must understand the technology and have the capacity to apply it.

The use of algorithms as electronic steps to follow in a decision-making process, although common in the age of technology, can create real challenges, both for decision-makers and public servants, as well as for the private sector involved in public procurement procedures (tenderers), given that technology is evolving rapidly and these algorithms can become increasingly sophisticated. Therefore, in Public Procurement Law, the need to regulate standard forms (eForms) arose.

By regulating them as eForms through the implementing regulation, they become the standard means of communication and information exchange in public procurement procedures, increasing the participation of economic operators in these administrative procedures.

Research Methodology

The study analyzes a form of expression of automated decision-making in public procurement, which is represented by standard forms for publishing notices in this field, known as eForms, on which the European Commission adopted the Implementing Regulation (EU) 2019/1780 [1]. It is an author's study, which analyzes the legal nature and implications of the eForms directive, respectively makes a theoretical analysis of eForms in the context of the new technology's development in public procurement.

Results

From Administrative Law in a Digital World to e-Procurement

The challenge for administrative law scholars as regards substantive law and legislation in the digital world is multi-faceted. From questions about how legislation ought to be drafted to facilitate and legitimize the use of certain technologies to the thorny questions that arise when traditional common law principles are applied to those technologies, it is clear there are no easy answers but there will be — and indeed already is — a demand for answers in practice. As these questions are answered, they will inevitably exert a profound effect on both administrative law and the shape of the administrative state in the digital world [2].

In the matter of public procurement, the new technologies are an opportunity to simplify and accelerate the procurement procedures. The digital transformation in this matter (e-Procurement) is important, because, according to the European Commission, a substantial part of public investment in the economy is spent through public procurement, representing 14 % of the EU GDP, making it a fundamental element of the investment ecosystem. Public authorities can use this lever in a more strategic manner, to obtain better value for each euro of public money spent and to contribute to a more innovative, sustainable, inclusive and competitive economy [3].

The Standard Forms and “Standartisation”: A Necessary Conceptual Delimitation

The regulation of standard forms is not equivalent to the adoption of standards in the standardization process.

The primary objective of standardisation is the definition of voluntary technical or quality specifications with which current or future products, production processes or services may comply; “standard” means a technical specification, adopted by a recognised standardisation body, for repeated or continuous application, with which compliance is not compulsory [4]. In the field of public procurement, the contracting authority can choose to reference the standard as a whole, or specific part(s) of the standard, describing products, systems, performance, symbols, terminology, construction or methods; the tenderers should document that their products and services comply with the relevant standard [5] .

The adoption of standard forms (eForms) is a part of the new technologies development in public procurement, concerning the administrative procedure in public procurement (automated decision-making). Thus, electronic means of information and communication can simplify the publication of contracts and increase the efficiency and transparency of procurement procedures.

The Implementing Regulation (EU) 2019/1780: Field of Application and Legal Nature from the Perspective of EU Directives

The Regulation (EU) 2019/1780 implements the European directives on public procurement remedies no. 89/665/EEC, 92/13/EEC and 2009/81/EC respectively public procurement directives no. 2014/23/EU, 2014/24/EU and 2014/25/EU.

According to Article 1 and Annex from this Regulation, are established the following standard forms:

► *Planning*: notice of the publication of a prior information notice on a buyer profile [Art. 48(1) of Directive 2014/24/EU (general directive); Art. 67(1) of Directive 2014/25/EU (sectoral directive); Art. 30(1) third subparagraph of Directive 2009/81/EC (defence directive); Prior information notice used only for information [Art. 48(1) of Directive 2014/24/EU (general directive)]; periodic indicative notice used only for information [Art. 67(1) of Directive 2014/25/EU (sectoral directive)]; prior information notice used only for information [Art. 30(1) of Directive 2009/81/EC (defence directive)]; prior information notice used to shorten time limits for receipt of tenders [Art. 27(2) of Directive 2014/24/EU, Art. 28(3) of Directive 2014/24/EU (general directive)]; periodic indicative notice used to shorten time limits for receipt of tenders [Art. 45(2) of Directive 2014/25/EU (sectoral directive)]; prior information notice used to shorten time limits for receipt of tenders [Art. 33(3) of Directive 2009/81/EC (defence directive)];

► *Competition*: prior information notice used as a call for competition [Art. 48(2) of Directive 2014/24/EU (general directive, standard regime); Art. 75(1)(b) of Directive 2014/24/EU (general directive, light regime); Art. 31(3) of Directive 2014/23/EU (concessions directive, light regime)]; periodic indicative notice used as a call for competition [Art. 67(2) of Directive 2014/25/EU (sectoral directive, standard regime); Art. 92(1)(b) of Directive 2014/25/EU (sectoral directive, light regime)]; notice on the existence of a qualification system [Art. 68 of Directive 2014/25/EU, Art. 92(1)(c) of Directive 2014/25/EU (sectoral directive)]; contract notice [Art. 49 of Directive 2014/24/EU (general directive, standard regime); Art. 69 of Directive 2014/25/EU (sectoral directive, standard regime); Art. 30(2) of Directive 2009/81/EC (defence directive, standard regime); Art. 75(1)(a) of Directive 2014/24/EU (general directive, light regime); Art. 92(1)(a) of Directive 2014/25/EU (sectoral directive, light regime)]; concession notice [Art. 31(1) of Directive 2014/23/EU (concessions directive, standard regime)]; subcontract notice [Art. 52(1) of Directive 2009/81/EC (defence directive)]; design contest notice [Art. 79(1) of Directive 2014/24/EU (general directive, design); Art. 96(1) first subparagraph of Directive 2014/25/EU (sectoral directive, design)];

- *Direct award prenotification*: voluntary ex-ante transparency notice [Art. 3a of Directive 89/665/EEC (general directive); Art. 3a of Directive 92/13/EEC (sectoral directive); Art. 64 of Directive 2009/81/EC (defence directive); Art. 3a of Directives 89/665/EEC and 92/13/EEC (concession directive)];
- *Result*: contract award notice [Art. 50 of Directive 2014/24/EU (general directive, standard regime); Art. 70 of Directive 2014/25/EU (sectoral directive, standard regime); Art. 30(3) of Directive 2009/81/EC (defence directive, standard regime); Art. 75(2) of Directive 2014/24/EU (general directive, light regime); Art. 92(2) of Directive 2014/25/EU (sectoral directive, light regime)]; concession award notice [Art. 32(2) (reference to Annex VII) of Directive 2014/23/EU (concession directive, standard regime); Art. 32(2) (reference to Annex VIII) of Directive 2014/23/EU (concessions directive, light regime)]; design contest result notice [Art. 79(2) of Directive 2014/24/EU (general directive, design); Art. 96(1) second subparagraph of Directive 2014/25/EU (sectoral directive, design)];
- *Contract modification*: contract modification notice [Art. 72(1) of Directive 2014/24/EU (general directive); Art. 89(1) of Directive 2014/25/EU (sectoral directive); Art. 43(1) of Directive 2014/23/EU (concessions directive)];
- *Change*: change notice, what it includes any other standard form and the Notice and Change sections from Table 2 of the Annex, for example notice about The European Public Procurement Procedure Identifier, a unique identifier of a procurement procedure.

According to the Article 2 of the Implementing Regulation (EU) 2019/1780, the standard forms referred to in Article 1 shall be used for the publication of the notices in the Official Journal of the European Union.

As established in Article 33(2) of Directives 2014/23/EU, Article 51(2) of Directive 2014/24/EU and Article 71(2) of Directive 2014/25/EU, notices are electronic files rather than paper documents. Their purpose is to achieve e-governance in the field of public procurement (e-Procurement), which is a close and reliable link between customers and suppliers and feedback, complaints and responses can be directly seen and dealt with [6].

Conclusion

In the matter of public procurement, the new technologies are an opportunity to simplify and accelerate the procurement procedures.

The regulation of standard forms is a part of the new technologies development in public procurement, concerning the administrative procedure (automated decision-making).

The standard forms for publishing notices, known as eForms, are the expression of automated decision-making in public procurement, regulated by Implementing Regulation (EU) 2019/1780. Their role is to increase the involvement of economic operators in administrative public procurement procedures and to increase the transparency of these procedures and contract execution, being established in various stages, respectively: planning, competition, direct award prenotification, result, contract modification, change notice.

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TECHNOLOGY AND CRIMINAL JUSTICE: A NECESSARY BALANCE IN THE DIGITAL ERA

Associate Professor Ramona Mihaela COMAN Ph.D.

*University of Medicine, Pharmacy, Science and Technology “George Emil Palade”, Faculty of Economics and Law /
Department of Law and Public Administration, President of “PRO IURE” International Association from Targu Mures, Targu
Mures, Romania*

Corresponding author: Ramona Coman: ramona.coman@umfst.ro

Abstract

The rapid evolution of digital technologies and the integration of artificial intelligence (AI) into various social systems have profoundly transformed the functioning of justice, including the criminal justice field. This paper explores the delicate balance between technological innovation and the fundamental guarantees of the rule of law within criminal proceedings and the execution of criminal sanctions. While the use of AI can enhance efficiency in case management, evidence analysis, and prediction of criminal behaviour, it also raises significant ethical and legal dilemmas regarding fairness, transparency, and protection of individual rights. The study examines the impact of digitalization on procedural safeguards such as the presumption of innocence, the right to a fair trial, and the right to defence. Furthermore, it emphasizes the need for an updated legal framework and a new model of legal education capable of preparing future professionals to address these challenges responsibly. The analysis combines doctrinal perspectives with current trends in judicial practice, underlining that technology must remain a tool serving justice — not replacing its human and moral foundations.

Keywords: criminal justice, artificial intelligence, digitalization, procedural safeguards, legal education, ethics

The Inevitable Integration of Technology in the Judicial System

“The criminal process is the mirror of society, so if the company is based on a constantly expanding and evolving technological arsenal, it is impossible for the technology to be ignored in the criminal process” [1].

Reflecting this societal transformation, it is thus unsurprising that rapid technological evolution, particularly that related to artificial intelligence, has generated a significant impact not only on daily life but also on the legal framework. Consequently, in recent decades, technological development, particularly related to artificial intelligence (AI), has had a significant impact on various areas, including the judiciary. Public law in general is constrained to change the content of concepts such as general interest and sovereignty, by assimilating principles aimed at net neutrality and regulation of digitalization, digital sovereignty, digital diplomacy [2].

Criminal justice is not alien to this constantly evolving phenomenon. The activity of discovering and investigating crimes committed through social networks, using artificial intelligence or advanced technologies generates great difficulties for the criminal investigation bodies. It is therefore necessary for them to turn to new technologies for the discovery of these

crimes. In order to comply with the principle of legality in criminal proceedings, it is necessary that the regulations in the criminal proceedings evolve in line with technological developments.

Over time, the criminal process has evolved under the influence of technology, witnessing the introduction of numerous informational tools:

- *Case Management and Transparency*: The implementation of electronic case management systems (such as the ECRIS portal, the *portal.just.ro* page, and the electronic file) facilitates the proper functioning of the rule of law by improving access to justice and making court decisions publicly available [3],
- *Procedural Efficiency*: Technology facilitates instant archiving, recording, processing, and transmitting of information. Furthermore, videoconferencing allows detainees to participate in court sessions in real-time, enhancing both procedural speed and the right to a hearing.
- *Discovery and identification*: Technology considerably facilitates the discovery of criminal facts and the identification of perpetrators. Examples include surveillance cameras for identifying offenders, GPS locations for determining their route, and the interception and recording of verbal, written, and ambient communications, which provide crucial information on the subject matter of the case [4].

The benefits of artificial intelligence in the criminal process are considerable, starting from an increased efficiency (due to artificial intelligence systems, complex analyses can be performed in a much shorter time than a person could realize), and reaching a deeper analysis (given the large number of information, a person would be unable to analyze in detail each aspect but artificial intelligence is able to analyze and identify patterns in the data provided with remarkable precision and depth).

Challenges of Using New Technologies in Criminal Proceedings

However, the use of new technologies in criminal proceedings inevitably raises questions regarding ethics, security, and fairness. Thus, a major challenge lies in the secure management of sensitive data, ensuring their integrity, and actively protecting personal information and privacy.

Thus, in the context of rapid technological progress, we encounter new categories of information that can lead to the identification of persons in criminal proceedings, information such as geo-localization data issued by mobile phone, tablet or car navigator, or data processed in financial card transactions [5].

At European Union level, Article 4 of the General Data Protection Regulation (Regulation no. 679 of 27 April 2016 on the protection of individuals with regard to the processing of personal data and on the free movement of such data by the European parliament and the Council of the European Union) provides that the location data of a natural person may contain information identifying it, therefore it may fall under the notion of "personal data" [6]. The statement of reasons for the Regulation specifies that individuals may be associated with online identifiers provided by their devices, applications, tools and protocols, such as IP addresses, cookie identifiers or other identifiers such as radio frequency identification tags. They may leave traces that, in particular when combined with unique identifiers and other information received by servers, may be used to create profiles of individuals and to identify them [6].

Traffic and location data allow tracking and identifying the source and destination of a telephone communication session based on the fixed or mobile phone of a person, and determining the date, time, duration and nature of it, identifying the mobile terminal equipment

used, locating the mobile phone without necessarily initiating communication, determining the frequency of user communications with certain people in the- a given period.

Both national and European regulations provide for clauses that in exceptional situations allow public authorities to intervene to collect citizens' data and, if necessary, monitor their movements. But the same regulations provide that the operation of data processing and supervision of individuals must be carried out within a defined legal context: the measures must be proportionate and appropriate and must also be subject to judicial review. That is, their use is not allowed unlimitedly and arbitrarily but is restricted to using those data that are relevant for the specific purpose for which they were collected.

Thus, for example, personal data collected for the purpose of combating epidemics cannot be processed for other purposes, such as tax checks, property checks, criminal cases. They must also be destroyed as soon as they become useless for the purpose for which they were collected.

Another challenge is use of artificial intelligence, for example in analysing a database, drawing conclusions based on previously introduced information. The algorithms on which an analysis made by artificial intelligence is based are influenced by the basic information introduced, and this can lead to discrimination (algorithmic bias).

At the same time, the functioning of the algorithms is not always fully understood nor accessible to the parties, which raises issues of transparency and equality before the courts (equality of arms).

Beyond the issues of transparency, the use of digitally generated evidence imposes strict requirements regarding evidence integrity and the right to contest. Technological systems must guarantee an uninterrupted digital chain of custody, employing cryptographic methods (such as hashing) to ensure that data have not been altered from the moment of collection until presentation in court. Furthermore, to maintain the fairness of the process, the accused must always have the right to request a human counter-expertise or to have access to an independent technical audit of the algorithmic results, thus guaranteeing an effective remedy against technological error.

Last but not least, an independent and impartial justice is one of the essential pillars of the rule of law and a crucial element in ensuring respect for human rights. According to European Convention on Human Rights, Article 6 (right to a fair trial), judges must be impartial and exercise their function independently [13], without any external influences that could affect the rights of parties involved in a judicial process [7, 8]. The right of an independent judge in the context of the ECHR refers to guaranteeing the independence of judges in the exercise of their judicial function, without any influence or pressure from other authorities or persons.

Whether we are talking about tools for algorithmic risk assessment, tools for interception or surveillance, or other forms of digitalization of the criminal process, these tools are usually created by private companies. The state does not have the possibility or the will to invest enough in research, thus resorting to the products and services of large companies. For their management it is often necessary to resort to the services of people who produce the acquired technology, being the only ones who have the necessary knowledge, which makes the criminal system go towards a progressive “privatization” [1, p. 1175].

Therefore, there are also many risks related to the restriction of some fundamental rights of the persons involved in the criminal process, and it is necessary to find a way to use these technological resources in accordance with the fundamental principles of the criminal process.

The real challenge thus concerns how judicial systems will be able, in the near future, to deal with these technological developments without becoming victims of them, and to frame their use to ensure respect for fundamental rights.

A Look into the Criminal Process in the Future

A perspective of new technologies, the digitalization of justice and especially the use of artificial intelligence, is represented by “predictive justice”, concept which in recent years has gained more and more popularity and has become a subject of major interest within the judiciary [10].

This refers to the use of information, data, and algorithms to predict the outcome of a legal process or a person's behaviour within a judicial system. An important aspect of predictive justice is the use of advanced technologies, such as artificial intelligence and data analysis, to identify patterns and trends in legal processes. These technologies can be used to analyse data from previous processes, predict possible results, and provide legal recommendations.

Predictive justice is basically digital processing, through algorithms, of huge amounts of data, in order to provide the parties or the judge with reliable predictions, quantified in percentage, on future issues. The algorithm allows the mechanical identification of a result by using data and a pre-established way of processing it [3].

Artificial intelligence is thus used in place of or to complement human reasoning.

One of the main advantages of predictive justice is the possibility of improving the efficiency and effectiveness of the judicial system. By using data analysis and algorithms, it is easier to identify cases with high potential for relapse or risk to society, which can contribute to increased public safety.

This instrument is considered advantageous in order to ensure a unitary application of the law and equality before it of all citizens, ensuring the homogeneity of outcomes in similar cases. Unlike subjective analysis, based on the experience and sensitivity of the judge, the use of predictive tools in the field of criminal law, is based on algorithms, which take into account a huge amount of data and rationalize them in a solid and simple forecast, represented in percentage terms or on a scale easily understandable (for example, on the danger of the defendant, determines whether it is small or on the contrary, very large) [9].

Basically, it makes a prediction based on court rulings in similar cases, or it can forecast the chances of a person relapsing. These tools appear to be useful to both the defence and the judge. Thus, the defence may foresee the possible outcome of a case and consequently adjust its strategy [10]. The judge may find it useful to resolve requests for conditional release, or to foresee the possibility that the suspect will commit new offences or evade prosecution if called to rule on a preventive measure [1, p. 1178].

Predictive justice can also help reduce costs associated with lengthy and complex court processes. By anticipating the possible results and identifying the best legal strategies, one can reduce the length of judicial processes and save financial and human resources.

Despite continued progress, however, there are still no programs that equal the human capacity to understand the context or make a critical analysis.

Although it is considered that the use of algorithms serves to make more objective and faster decisions, in reality it could become an element of discrimination. Thus, a judge who normally relies solely on his or her own experience and some relevant data for the accused person, such as the criminal record, could receive useful and rapid help from predictive algorithms, giving him or her an assessment of the risk of fleeing or committing new crimes (on a hypothetical or percentage risk scale). Since the algorithm works on the objective basis of a mathematical formula that processes a huge amount of data entered into the program and which refers to several factors considered relevant for the purpose of calculating the risk of escape or relapse of people (age, work, family status), it can create algorithms in which people of a certain race

or gender, age or occupation, or they would be presented with a higher degree of danger, due to the data and information that were provided to the program [11]. Therefore, it cannot be said that predictive justice would have absolute neutrality.

The lack of relevant information on their functioning and, consequently, the difficulty of challenging their findings in court, in particular by the persons investigated, mean that their use is prejudicial to the rights of the defence and the equality of arms in the administration of evidence, which are essential principles of the criminal process.

Moreover, the human decision brings with it the idea of understanding, of reasonable appreciation of the characteristics of the individual who presented himself before the judge, the decision being based on and a component of emotional intelligence, as well as the sense of responsibility, the burden of which can be felt only by a human being.

Last but not least, those situations in which a judge would normally make the *in dubio pro reo* principle applicable, the algorithms eliminate them. The algorithm has no doubts, and a high-percentage result would lead some judges to move from doubt to firm conviction [11, p. 115].

In conclusion, predictive justice is a significant development in the judicial system, which will bring many benefits to both litigants and judicial authorities. However, it is important that the use of this technology is done with responsibility and in accordance with legal and ethical principles, to ensure the protection of individual rights and privacy.

The Need for Digital Education among Legal Professionals

The future of the criminal process in the context of digitization is announced to be extremely dynamic, full of opportunities and challenges. The implementation of digital technologies in the judicial system promises to bring a number of benefits, but at the same time raises questions about data protection, information security, and respect for individual rights.

It is essential that the judiciary is prepared to face challenges and reap the benefits of digital technologies to improve access to justice and the efficiency of judicial processes.

The criminal process must ensure respect for the rights of the defence, the presumption of innocence, equality before the law, the right to an independent court, and respect for the rights provided by law; therefore any assimilation of new technology in criminal proceedings, even if useful for the efficiency of the criminal investigation activity, must not be done automatically, without an analysis of the risk produced and the actual need.

So, the question is not whether we use AI in criminal trials, but how responsibly we use it. And this is where the human factor comes in: digital legal education. Magistrates, lawyers, police officers, prosecutors – all need to understand both the benefits and the limits of technology. In Italy, one of the Union states that transposed the regulations most rapidly at national level, on 10 October 2025, a law transposing this regulation on artificial intelligence came into force - it is Law 132/2025; although it allocates only one article to justice, Article 15 provides for the duty of the minister of justice to ensure the didactic training of magistrates and administrative staff on the use of artificial intelligence, including on awareness of benefits and risks. This is essential in the administration of evidence, as the use of artificial intelligence can support judicial bodies in the rapid analysis of a large volume of data (for example, in the identification of patterns in electronic communications, in facial recognition) by reducing the duration of investigations, but at the same time there may be algorithmic errors or prejudices (bias) that affect the correctness of the analysis (for example, misidentifications, inappropriate

statistical interpretations, or automated processing that violates privacy). The lack of rigorous human control can lead to distortion of judicial truth.

That is why it is essential for magistrates, but also for the other participants in the criminal process, to be aware of both the benefits and the limits of artificial intelligence. Adequate knowledge of how these technologies work allows them to be used without abdicating the fundamental principles of the criminal process.

Without a deep internal understanding of the technology, the judicial system exposes itself to the risk of becoming dependent on the private companies that supply these tools. This dependence affects not only the public budget but also decisional sovereignty. If a judge or prosecutor does not understand the internal logic of an AI tool, they effectively become passive users of a solution whose real control belongs to an external commercial entity. Furthermore, in case of a dispute concerning intellectual property or maintenance, the continuity of justice (uninterrupted access to case files and e-discovery systems) may be compromised. Therefore, digital education is not just about using technology, but about developing an internal capacity for oversight and control that protects the institutional integrity of the judiciary.

Since human reasoning, unlike artificial intelligence, enjoys creativity, empathy, flexibility, ability to understand context, a sense of ethics and responsibility, human decision will not be replaced by artificial decision, created by a digital system. Regardless of the technological evolution of the future, in the criminal process, artificial intelligence can only come to the aid and completion of human decision, not in its place.

Conclusions

The analysis demonstrated that the adoption of technology, from basic case management systems (ECRIS) to advanced predictive justice models, offers undeniable benefits. AI systems promise increased efficiency and homogeneity of outcomes by analyzing vast datasets quickly and rationally. These tools can significantly aid judicial authorities and defence counsel by providing forecasts for recidivism risk or case outcomes, thereby accelerating processes and potentially saving resources.

Despite its potential, the digital future of the judiciary is marked by significant risks that require immediate regulatory intervention: risk to fundamental rights, such as the right to silence and presumption of innocence, the lack of transparency regarding the internal functioning of algorithms and the risk of algorithmic bias (discrimination based on historical data), the necessary reliance on private tech companies for creating and maintaining AI tools, that introduces a risk of progressive privatization of the judicial function. Without adequate digital literacy among legal professionals, the system risks becoming dependent on external entities, potentially compromising the institutional integrity and decisional sovereignty of the state.

Crucially, this paper established that technology can only serve as a complement to, and not a replacement for, human decision-making. The essence of the judicial function — the ability to exhibit creativity, empathy, flexibility, contextual understanding, and a sense of responsibility — remains exclusive to the human judge. An AI-generated high-risk score should not allow the judge to abdicate their human duty to assess individual characteristics and apply the *in dubio pro reo* principle where doubt persists.

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AI, ETHICS, AND THE PROTECTION OF FUNDAMENTAL HUMAN RIGHTS

Assist. Prof. Roxana Silvia TRUȚA Ph.D.

George Emil Palace University of Medicine, Pharmacy, Science and Technology from Tg-Mureș, Faculty of Economics and Law / Department of Law and Public Administration, Romania
Corresponding author: Roxana Silvia TRUȚA: roxana.truta@umfst.ro

Abstract

The transformations generated by digitalization have a significant impact on the exercise of fundamental rights, influencing essential aspects such as privacy, freedom of expression and equal access to resources and opportunities. While emerging technologies such as artificial intelligence and big data analytics bring important benefits to society, they also raise complex legal issues, related to personal data protection, digital surveillance and the risks of algorithmic discrimination.

This paper examines both the challenges and opportunities offered by technological innovation from the perspective of fundamental rights. It examines the effectiveness of current regulations and their ability to respond to the new risks posed by digitalisation, underlining the need for legislative adaptations to ensure effective protection of citizens.

The study also explores the role of national and international authorities in monitoring the impact of new technologies on human rights, highlighting the importance of collaboration between governments, non-governmental organizations and the private sector. Solutions are proposed to strengthen legal protection, including through more flexible regulatory measures and the implementation of ethical principles in the development of digital technologies.

In conclusion, guaranteeing respect for fundamental rights in the digital age requires a balanced approach that promotes both technological innovation and legal and social responsibility, thereby ensuring a sustainable framework for a fair and inclusive digitalised society

Keywords: Fundamental rights, digital age, guarantees, legal responsibility, digitalised society, artificial intelligence.

1. Preliminaires

Accelerated technological evolution has profoundly reshaped the way people communicate, work, and access information, directly influencing the exercise of fundamental rights. Digitalization brings significant opportunities for the development of society, but at the same time generates major risks, such as possible intrusions into respecting privacy safeguards, limiting freedom of expression, and algorithmic discrimination [1].

The digitization process refers to rendering information into an easily accessible electronic format using digital devices based on hardware and software components [2]. Basically, analogue information recorded on physical media, such as documents, images, and photographs, is converted into a digital format [3].

The term “digitalization” refers to the incorporation of all fields of activity into the digital sphere. In Romania, based on recent technological and societal developments, it was considered

necessary to establish a representative authority within the executive power, materialized through the Authority for the Digitalization of Romania, created by Government Decision no. 89/2020, published in the Official Gazette no. 113 of 13 February 2020. The RDA coordinates the implementation of public strategies and policies in the field of digital transformation and the information society.

With the spread and emergence of new technologies, specific legal regulations have become necessary, and science and technology have increasingly become formal sources of law [4].

The legal environment must identify a proper balance and address new forms of human rights violations caused by the use of emerging technologies, correlating the development of fundamental rights with the requirements of a contemporary knowledge-based society. Fundamental rights are subjective in nature, representing an individual's legally protected ability to act or refrain from acting, and to invoke legal protection against third parties in order to safeguard legitimate interests [5].

2. Fundamental Rights in the Digital Age. Definition and Challenges

Fundamental rights refer to inherent rights possessed by individuals, protected by laws, constitutions, and international treaties [6]. These rights include, but are not limited to, the right to privacy, freedom of expression, non-discrimination, and the right to a fair trial within a reasonable time [7].

At the national level, several fundamental rights are regulated by Articles 21–31 of the Romanian Constitution, ensuring free access to justice, the right to life and physical and mental integrity, individual freedom, rights of defense, private and family life, freedom of expression, and the right to information [8].

At the European level, Romania has transposed the European Convention on Human Rights into national law through Law no. 30/1994, ratifying both the Convention and its additional protocols [9].

In the context of digital evolution, the impact of technology on the protection and guarantee of fundamental rights is increasingly evident, given the vulnerabilities faced in this domain [10].

The use of artificial intelligence in law enforcement involves several potentially unacceptable risks, including lack of transparency in decision-making, algorithmic discrimination, risks to privacy and personal data protection, as well as threats to the presumption of innocence and equality of arms [11].

At the same time, artificial intelligence systems used by judicial authorities are vulnerable to cyberattacks and data poisoning practices, which introduce incorrect data sets in order to produce biased or unreliable results [12].

In order to prevent and mitigate situations affecting the judicial systems in the European States, a number of ethical principles relating to the use of artificial intelligence in judicial systems have been regulated through the European ethical Charter.

These principles identified and regulated at the Charter level are enshrined as fundamental principles to be respected in the development of artificial intelligence in justice, namely: Respect for fundamental rights, non-discrimination, quality and security of justice, transparency, impartiality and fairness and the '*under user control*' principle.

Between the need to prevent the dangers of artificial intelligence and the desire to remain competitive with other global actors, such as the United States and China, the European Union has adopted an unprecedented legal framework regulating artificial intelligence [13].

Article 50 of *Regulation* (EU) 2024/1689 expressly provides for the guarantee of a high level of protection of public interests and respect for fundamental rights by establishing a system of transparency obligations for providers and implementers of AI systems.

The Right to Privacy and Protection of Personal Data

The principle of privacy is a concept that cannot be exhaustively defined, as any definition would inherently limit its scope [14]. Legal doctrine has emphasized the contextual nature of privacy, relating it to the social and historical environment in which individuals live [15].

Article 12 of the Universal Declaration of Human Rights states that “*everyone has the right to respect for his private and family life, his domicile and correspondence.*”

On the other hand, the right to the protection of personal data has a narrower scope, but which gives it effective legal protection.

With regard to European-level regulations on the right to the protection of personal data, Regulation EU 2016/679 of the European Parliament and of the Council of 27 April 2016 establishes an extremely well-established framework for the protection of personal data, paragraph 10 for the following reasons: *‘in order to ensure a consistent and high level of protection of natural persons and to remove obstacles to the movement of personal data within the Union, the level of protection of the rights and freedoms of natural persons with regard to the processing of such data must be equivalent in all member states Consistent and homogeneous application of the rules on the protection of fundamental rights and freedoms of natural persons with regard to the processing of personal data should be ensured throughout the Union. In relation to the processing of personal data for the purposes of compliance with a legal obligation, the performance of a task carried out in the public interest or in the exercise of official authority vested in the controller, member states should be allowed to maintain or introduce provisions of national law that further clarify the application of the rules of this regulation (...)*

Transposed at national level by the GDPR Regulation (2018), the right to the protection of personal data has its own legal regulation. Through the safeguards established by the GDPR Regulation, the use and handling of personal data are activities with express regulation, so that possible management of such data without complying with the mandatory legal conditions could involve an intrusion into privacy or privacy.

Increased attention must be given to the jurisdictional phases that are based on the processing of “personal data”. These data may concern ethnic origin, sexual orientation, religious or philosophical belief, socio-economic conditions, Union membership, political opinions, health conditions.

Freedom of Expression and the Right to Information

“Everyone has the right to freedom of speech. This right includes freedom of opinion and the freedom to receive or communicate information or ideas without interference from public authorities and without regard to borders. This Article shall not prevent States from subject broadcasting companies to a prior authorization regime. The exercise of these freedoms, involving duties and responsibilities, may be subject to certain formalities, conditions, restrictions or penalties provided for by law, which constitute necessary measures in a democratic society for national security, the defense of order and the prevention of crime, the protection of health or morals, the protection of the reputation or rights of others, to prevent

the disclosure of confidential information or to guarantee the authority and impartiality of the judicial system.

The right to freedom of expression enjoys superior regulation on fundamental human rights. Freedom of expression is based on the dignity, reasoning and autonomy of the individual, traits without which he cannot exist or cannot externalize himself.

Moreover, freedom of expression is the foundation of the democratic regime, guaranteeing its existence and functioning, being impossible to consolidate in a society in which the individual is forbidden to express his own opinions and ideas, to check the information he receives and to filter them, as well as the possibility to analyze, analyze, analyze, analyze, analyze, analyze and analyze. discuss and discuss them.

However, the exercise of the right to freedom of expression also includes an obligation to verify, namely a filtering of the information that is transmitted through various media channels.

Disinformation online through the spread of fake news aimed at influencing public opinion is a major challenge, affecting the public's right to accurate and reliable information.

The problems arising from disinformation lead to the monopolization of information flow by various technology companies and raise doubts about fair access to information, namely the respect and guarantee of the right to information.

The right to information is a right complementary to the right to freedom of expression, referring to the possibility of individuals seeking, receiving and disseminating information and idea. With the new era of digital technology, this right has become essential for government transparency and accountability of public authorities [16].

The negative consequences and the extent of the phenomenon of fake *news au information* led in recent years to act at international level, to diminish and protect citizens.

New techniques used by people interested in transmitting false information online are based on various algorithmic manipulations, whereby platforms prioritize content that generates strong reactions, which can lead to the creation of "informational bubbles" and social polarization.

Freedom of expression and the right to information are essential for a democratic society but must be protected by balanced measures that respect other fundamental rights.

People must be educated to identify credible sources and not be influenced by propaganda and manipulation. In this regard, some states have recognized internet access as a fundamental right, for exercising the right to information, therefore considering the internet as an essential service.

The Internet is essential in citizens' lives, especially in the relationship of citizens with public institutions and authorities. The need to strengthen interest in internet access or at least a "clean" internet must be supported by states and possibly the European Union. The examples given in the article indicate that the internet is not only a means of leisure but is closely linked to citizens' obligations in a democratic society. Access to the internet must be equal and non-discriminatory, so that States are obliged to help vulnerable people and address current problems with location monitoring, voice monitoring, profiling, collecting and selling certain types of data on a large scale.

Another problem that has arisen in the field of freedom of expression is the risk of online censorship. This risk poses one of the biggest challenges for freedom of expression in the digital age. Freedom of speech has certain limits.

If we were to provide a definition of this notion, online censorship refers to the restriction or removal of digital content by governments, technology platforms or other entities, the result being preventing users from accessing or distributing certain information in various ways

(blocking access to websites, deleting content from digital platforms, limiting the visibility of content through various algorithms, suspending or banning user accounts, etc.).

The Right to Non-discrimination and the Impact of Algorithms on Social Equity.

The right to non-discrimination is a fundamental principle of any democratic society, guaranteeing equal treatment for all citizens, regardless of race, gender, age, religion, gender, gender, gender, gender and gender. sexual orientation or other protected characteristics. In the age of digitalization and artificial intelligence, automated decisions based on algorithms affect more and more aspects of social, economic and professional life. Although technology has the potential to increase efficiency and transparency, the use of algorithms can amplify social inequalities and perpetuate existing prejudices.

The right to non-discrimination is recognized and protected by several international treaties, national laws and directives of the European Union.

With regard to the use of AI in respect of the right to non-discrimination, although discrimination appears to be the sole result of subjective assessments of persons or authorities called upon to apply the law, by experimental means, it has been found that AI, based on the results provided by statistics, it can apply the law in a discriminatory manner [17].

Algorithms are sets of rules and instructions used by computer systems to analyze data and make decisions. By customizing artificial intelligence algorithms, they are trained on historical data sets that may contain racial, gender, or economic prejudices. If the data used is biased, the algorithmic decisions will reflect and perpetuate these inequalities, therefore it is imperative that the rules used in the field of artificial intelligence algorithms are subject to constant checks and analyzes.

3. Conclusions

In relation to the impact of new technologies on society, national and international legislation must be constantly adapting to these new circumstances. One question is whether or not traditional legal concepts are versatile enough to cope with this new digital world?

In this regard, we believe that it is necessary to create and develop an appropriate legal framework, so that legal systems need to evolve to balance new technologies (artificial intelligence, blockchain, big data) and the protection of fundamental rights, ensuring effective protection of fundamental rights, such as privacy, freedom of expression and data security.

In conclusion, the digital age brings enormous opportunities for innovation and development, but requires a balanced and proactive legal approach to prevent the associated risks. Close cooperation between states, international institutions, companies and civil security is essential.

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ARTIFICIAL INTELLIGENCE: CHALLENGES AND LIMITATIONS IN TEACHING THE HISTORY OF THE ROMANIAN STATE AND LAW TO LAW STUDENTS

Associate Professor Călin FLOREA Ph.D.

"Dimitrie Cantemir" University of Târgu Mureș, Faculty of Law, Romania
Corresponding author: Călin FLOREA: calinflorea_ms@yahoo.com

Abstract

The integration of artificial intelligence (AI) into the educational process has become one of the most significant transformations in contemporary higher education. In the legal field, particularly in teaching the History of the Romanian State and Law, the use of AI-based tools raises both methodological and ethical opportunities and challenges. The purpose of this study is to analyse the limits and potential of artificial intelligence in developing historical and legal competencies among law students. Firstly, the paper highlights AI's ability to facilitate rapid access to historical sources, legal documents, and complex doctrinal interpretations, thereby contributing to the personalization of teaching and the stimulation of critical thinking. Secondly, it addresses the risks generated by excessive reliance on algorithms, errors in historical contextualization, and the tendency to oversimplify the learning process through automation. Furthermore, it discusses issues related to academic integrity, research originality, and the cultivation of legal reasoning, which is essential in university-level legal education. The analysis emphasizes the need for a balanced approach, in which the law professor remains the critical mediator between authentic historical knowledge and emerging technological tools. The main conclusion is that artificial intelligence should not be regarded as a substitute for the educational act, but rather as a complementary partner capable of optimizing the teaching process when used responsibly, reflectively, and in integration with traditional pedagogical methods. Thus, the future of teaching the History of the Romanian State and Law depends on the academic community's ability to harness technological potential without sacrificing scientific rigor and the humanistic dimension of legal education.

Keywords: Artificial intelligence, Legal education, History of the Romanian State and Law, Pedagogical challenges, Academic ethics.

Introduction

In recent decades, artificial intelligence (AI) has transformed the educational field, providing innovative tools for personalized learning, data analysis, and the optimization of teaching processes [1]. In the context of legal education, AI can support the development of students' analytical skills and their complex understanding of the evolution of the Romanian state and law an area that involves both historical knowledge and an understanding of legal and institutional principles [2].

The teaching of the history of the Romanian state and law aims to familiarize students with the evolution of legal norms, political institutions, and the socio-cultural context in which they

were formed. Integrating AI into this field brings significant opportunities but also challenges and limitations that must be critically analysed to maintain academic rigor and the development of critical legal thinking [3].

The profound transformations brought by the digital revolution have significantly redefined how knowledge is produced, transmitted, and received, including in the field of legal education. Artificial intelligence (AI), as an expression of technological progress and informational automation, has begun to play an increasingly important role in higher education, offering tools capable of optimizing access to information, personalizing educational paths, and stimulating students' analytical thinking. In the context of teaching the history of the Romanian state and law, AI opens new perspectives from facilitating quick access to legal and historical sources to creating interactive simulations and educational scenarios that allow exploration of the evolution of state institutions and the legislative system in a dynamic and interactive manner.

However, the introduction of artificial intelligence into legal education is not without challenges. The complexity of historical and legal phenomena, the interpretive nature of historical analyses, and the nuances of legislation raise significant issues for digital tools, which may offer standardized responses but cannot replicate critical judgment or deep academic reflection. Moreover, excessive reliance on technology may diminish students' ability to evaluate sources, build coherent arguments, and integrate multiple perspectives—highlighting the need for a balanced and critical approach.

This paper aims to explore both the potential and the limits of using artificial intelligence in teaching the history of the Romanian state and law to law students. By analysing pedagogical challenges, ethical aspects, and practical implications, it seeks to identify ways in which AI can be effectively integrated into the educational process without compromising theoretical rigor and the development of critical thinking elements essential for shaping the legal competencies of future professionals.

1. Theoretical Foundations

Teaching the History of the Romanian State and Law in higher legal education is based on a solid theoretical foundation, involving both historical and legal knowledge, as well as the development of students' critical and analytical skills. This discipline plays an essential role in the training of future legal professionals, providing them with the historical context of Romanian institutions, principles, and legal norms, as well as an understanding of the evolution of the national legal system in relation to external influences and socio-political changes.

The theoretical foundation represents the core of any educational process and involves explaining and justifying the taught content based on recognized historical and legal theories. In the case of the History of the Romanian State and Law, this includes:

- **Identifying and presenting historical and legal sources:** From ancient codes and laws (such as Caragea's Code or the Organic Regulations) to modern legislation.
- **Integrating the social and political context:** The study of the transformation of state and legal institutions must be correlated with the historical events that determined their evolution.
- **Developing critical thinking:** Students are encouraged to analyse sources, identify continuities and ruptures, and formulate solid historical and legal arguments.

The integration of artificial intelligence into the teaching process can become an innovative tool in strengthening the theoretical foundation of the discipline by:

- **Providing rapid access to historical and legal data:** AI-based platforms can facilitate the automatic collection and analysis of historical and jurisprudential documents, reduce research time and increase accuracy.
- **Personalizing learning:** AI algorithms can identify students' strengths and weaknesses in understanding theoretical concepts and suggest supplementary materials adapted to each student's level.
- **Simulations and historical-legal scenarios:** AI can generate interactive case studies, allowing students to explore legal decisions in different historical contexts, thereby reinforcing the link between theory and practice.
- **Analysing and synthesizing information:** Natural language processing tools can help draft theoretical syntheses, compare laws, and highlight the evolution of legal concepts.

However, integrating AI into teaching the History of the Romanian State and Law is not without challenges:

- **Academic rigor:** Information provided by AI must be verified and correlated with recognized academic sources.
- **Developing critical competencies:** Students must learn not to passively accept AI-generated information, but to analyse and contextualize it.
- **Teacher training:** Professors must acquire digital competencies and integrate AI pedagogically, without reducing human interaction or critical debate.

The theoretical foundation remains indispensable for teaching the History of the Romanian State and Law, ensuring the coherence of historical-legal knowledge and the development of students' critical thinking. Integrating AI offers new opportunities for efficiency and personalized learning, but it must be approached with methodological care to avoid diminishing scientific rigor or students' capacity for independent analysis. In this sense, AI becomes a **complementary tool** that supports and amplifies the theoretical foundation but cannot replace it. Teaching this subject involves interpreting historical context, analysing legislation, and understanding institutional mechanisms activities that require not only memorization but also the development of critical thinking and legal reasoning skills, which AI can support but not fully substitute [4].

2. Challenges in Integrating AI into Teaching the History of the Romanian State and Law

2.1 Dependence on algorithms and reduced critical analysis, students may become dependent on AI for identifying sources or explaining legal and historical events, which can limit the development of analytical and interpretive skills [5].

2.2 Algorithmic bias and impartiality, AI systems are trained on existing data, which may reproduce historical or legal interpretations influenced by ideological biases or dominant perspectives, insufficiently including minorities or controversial periods [6].

2.3 Evaluating legal and historical complexity, AI can verify the accuracy of historical data or current legislation but cannot assess the quality of legal reasoning or the interpretive subtleties of the history of law [7].

2.4 Lack of human interaction and mentorship. In legal studies, discussions with professors and critical debates are essential. AI cannot reproduce the exchange of ideas and personalized guidance offered by a human instructor.

3. Limits of AI in Teaching the History of the Romanian State and Law

3.1 Epistemological limitations AI can process and organize historical and legal data but cannot generate original knowledge or critical reinterpretations of primary sources, which are essential in the study of Romanian law [8].

3.2 Ethical and privacy issues, collecting data about students' progress and performance for AI use raises concerns about personal data protection and academic confidentiality [9].

3.3 Impact on legal thinking, Teaching law and state history involves developing the ability to argue, interpret critically, and evaluate precedents. Dependence on AI may diminish these essential skills [10].

3.4 Practical limitations, AI cannot replace legal simulations, classroom debates, or the detailed analysis of historical Romanian legislation activities fundamental to the full training of a jurist.

4. Implications for Law Students' Training

Integrating AI into teaching the history of the Romanian state and law can be beneficial if used as a **support tool**:

- for exercising critical thinking through simulated historical and legal scenarios.
- for quick access to legislative and historical sources.
- for adapting teaching to each student's level of preparation.

Professors must oversee how AI is used and integrate complementary activities that stimulate debate, critical interpretation, and argumentative analysis competencies essential for future jurists. Artificial intelligence represents a significant opportunity for modernizing the teaching of the history of the Romanian state and law, providing tools for analysis, simulation, and personalized learning. However, challenges related to algorithmic dependence, bias, epistemological limits, and the impact on legal reasoning require a **critical and balanced** approach.

AI should be viewed as a **complementary instrument** to the professor supporting, not replacing, the learning process. In this way, students can develop both technical competencies and critical thinking and legal argumentation skills essential for their professional careers.

In the context of globalization and accelerated digitalization, artificial intelligence (AI) has become an innovative tool in education, offering possibilities for personalized learning, data analysis, and the optimization of pedagogical processes [11]. In the field of legal education, AI can support the development of analytical competencies, legal reasoning, and a complex understanding of evolution Teaching the history of the Romanian state and law aims to familiarize students with the evolution of legal norms, political institutions, and the social context in which they developed. This discipline requires not only the memorization of facts but also the development of analytical, critical interpretation, and legal reasoning skills. Within this framework, Artificial Intelligence (AI) offers significant opportunities, but also raises challenges and limitations that must be rigorously assessed [12].

5. Impact on Legal Thinking

Dependence on AI may diminish the development of argumentation skills, critical interpretation, and the ability to evaluate legal precedents [13]. The integration of Artificial Intelligence into the educational process represents a significant opportunity for developing students' legal reasoning, particularly in the study of the history of Romanian law. The use of AI-based platforms and applications allows rapid access to complex sources, historical legislative texts, and comparative analyses, facilitating a deeper understanding of the evolution of legal norms within their social, political, and cultural contexts.

Through AI tools, students can develop critical analysis, synthesis, and argumentation skills, being encouraged to identify connections between past legal principles and their applicability in contemporary law. Furthermore, AI can personalize the learning process by adapting to each student's individual pace and providing immediate feedback, thereby strengthening legal reasoning competencies. However, the use of technology requires a balanced approach to avoid excessive reliance on digital tools and to preserve the development of independent critical thinking. In conclusion, when strategically integrated into the teaching of the history of Romanian law, AI can serve as a catalyst for complex legal thinking, preparing students for future professional challenges.

6. Practical Limitations

AI cannot replace legal simulations, debates, and the detailed analysis of historical codes and institutions activities fundamental to the training of future jurists. Although Artificial Intelligence has demonstrated impressive capacity for processing information and generating legal content, it presents significant limitations in the context of legal education.

Firstly, AI cannot replicate the practical experience provided by legal simulations, where students develop essential skills such as oral argumentation, negotiation, and decision-making in complex situations. Moreover, legal debates involve not only knowledge of legal norms but also the ability to interpret their nuances, anticipate counterarguments, and adapt reasoning in real time competencies that require human interaction and critical reflection.

Additionally, the detailed analysis of historical codes and institutions involves not merely memorizing legal articles but also understanding the social, political, and cultural contexts in which they emerged. While AI can provide summaries or interpretive suggestions, it cannot reproduce the comprehensive experience of critical study of legal tradition and precedent, which is essential for forming a complete and responsible jurist. Thus, although technology can be a valuable support tool, it cannot substitute for the complex processes of critical thinking, debate, and simulation that define quality legal education.

7. Case Studies and Practical Examples

7.1 Analysis of the Romanian Civil and Criminal Codes

AI can be used for the rapid comparison of historical versions of legal codes and the identification of major legislative changes. For example, AI-based platforms can generate comparative tables between interwar and contemporary codes, highlighting the evolution of legal principles [14].

7.2 Simulations of Historical Trials

AI systems can create interactive simulations of historical legal proceedings, helping students understand the historical context of judicial decisions. This approach develops their capacity for critical analysis and interpretation of legal norms according to historical circumstances [15].

7.3 Adaptive Learning Platforms

Intelligent tutoring systems can offer personalized exercises testing knowledge of Romanian institutions, the evolution of the Constitution, and relevant legislation. Such platforms allow for the evaluation of individual progress and the adjustment of materials to each student's needs [16].

Educational Activity	Traditional Method	AI Support	AI Advantages	AI Limitations
Analysis of the Civil Code	Reading, discussion	Automatic comparison	Speed, visualization of evolution	Lacks nuanced legal interpretation
Historical case studies	Seminar, debates	Interactive simulation	Practical experience, interactivity	Lacks instructor feedback
Knowledge testing	Written tests	Adaptive evaluation	Personalization, progress monitoring	Limited to factual responses

8. Recommendations for Integrating AI in Teaching the History of the Romanian State and Law

In the context of deep digital transformations in education, Artificial Intelligence has become an increasingly present tool in teaching and learning. The discipline “*History of the Romanian State and Law*” with its theoretical and analytical nature, is particularly well positioned to benefit from AI applications, given the complexity of historical and legal sources and the necessity of developing student's critical thinking.

8.1 Advantages of Integrating AI

Firstly, AI can facilitate rapid access to diverse information and resources. Students can use AI-based applications to consult legal databases, historical codes, comparative legislation, and case studies, enabling a broader and more contextualized understanding of the evolution of Romanian law. Thus, the time spent searching for and selecting primary sources can be significantly reduced, allowing for deeper critical analysis.

Secondly, AI can support personalized learning. Intelligent platforms can adapt didactic content according to each student's knowledge level and learning pace. This allows for the identification of knowledge gaps and the recommendation of supplementary materials, contributing to a more solid and individualized legal education.

Another significant advantage is the possibility of simulating legal scenarios and analyses. AI tools allow for the creation of interactive tests, virtual case studies, or simulations of the application of legal norms in various historical contexts, fostering analytical, argumentative, and problem-solving abilities.

8.2 Limitations and Challenges

However, the use of AI in teaching “*The History of the Romanian State and Law*” is not without limitations. The primary risk is overdependence on technology. Students who rely excessively on AI tools may develop a passive learning approach focused on obtaining quick answers, at the expense of critical thinking and independent interpretation of historical and legal sources.

The quality of AI-generated information can also vary. Algorithms may select or synthesize incomplete or inaccurate data, which requires continuous critical oversight by instructors and the training of students in source verification. Another aspect is ethical and pedagogical: reliance on AI raises concerns regarding the assessment of genuine student competencies, academic integrity, and the development of independent research skills. Additionally, technological integration requires adequate funding and infrastructure, which may pose challenges for some institutions.

8.3 Recommendations for Effective Implementation

To maximize benefits and minimize risks, the following measures are recommended:

- Integrate AI as a **complementary tool**, not a substitute for traditional teaching.
- **Train instructors and students** in the critical use of AI tools to ensure proper evaluation of sources and information.
- **Create structured digital resources** that enable interactive simulations and case studies while maintaining a focus on historical and legal analysis.
- **Promote active learning** by combining AI-assisted activities with debates, research, and critical writing.
- **Regularly assess the impact** of AI on student performance and competencies to adjust pedagogical strategies accordingly.

The use of AI in teaching the *History of the Romanian State and Law* presents multiple advantages rapid access to information, personalized learning, and stimulation of analytical skills. However, successful integration depends on maintaining a balance between technology and traditional pedagogy, adequate instructor and student training, and continuous critical evaluation of sources and outcomes. Through a responsible approach, AI can become a valuable ally in the professional formation of future jurists.

9. Conclusion

Artificial Intelligence represents a valuable resource for modernizing the teaching of the history of the Romanian state and law, offering tools for analysis, simulation, and personalized learning. Challenges such as algorithmic dependence, bias, and epistemological limits require a critical and balanced integration. AI should serve as a support mechanism for developing legal and historical competencies, stimulating critical thinking, argumentation, and understanding of historical context elements essential to the formation of future jurists.

The analysis of AI’s role in teaching the history of the Romanian state and law highlights both the opportunities and the limitations of this emerging technology within legal education. AI can facilitate access to complex historical information, provide interactive resources, and enable legal simulations and didactic scenarios that allow students to understand the evolution of Romanian state institutions and law analytically and critically.

Nevertheless, the integration of AI in legal and historical education faces numerous challenges. Excessive reliance on automatically generated information may hinder students' critical thinking and their ability to interpret historical and legal contexts. Moreover, AI cannot fully reproduce the subtlety and complexity of academic judgment, historical interpretation, or legislative nuance elements vital for the professional development of jurists. Ethical and data security issues, along with the need for proper instructor training, further complicate implementation.

Thus, the use of Artificial Intelligence in teaching the *History of the Romanian State and Law* should be viewed as a **complement**, not a **substitute**, for traditional pedagogy. Within a balanced educational framework, AI can stimulate scientific curiosity, foster analytical competence, and encourage interdisciplinary exploration. However, its success depends on responsible and critical integration into the educational process. The identified challenges point toward future directions for research and pedagogical experimentation aimed at optimizing the use of digital technologies without compromising the theoretical and critical foundations of legal education.

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HUMANIST EDUCATION IN TRANSITION: RECONCEIVING THE UNIVERSITY PARADIGM OF TEACHING AND LEARNING

Assoc. Prof. Doina DAVID Ph.D., Assoc. Prof. Călin FLOREA Ph.D.

“Dimitrie Cantemir” University of Târgu Mureș, Faculty of Law, Targu Mureș, Romania
Corresponding - Doina DAVID: daviddoina@yahoo.com; Călin FLOREA: calinflorea_ms@yahoo.com

Abstract

Contemporary humanistic education is undergoing a complex process of transition, driven by the social, technological, and cultural changes of the globalized world. The traditional university paradigm centered on the transmission of knowledge and on classical intellectual formation is being challenged by the new demands of the knowledge society and by the emergence of an educational model focused on competencies, interdisciplinarity, and lifelong learning. In this context, the reconceptualization of the university paradigm requires a rebalancing between the humanistic and the pragmatic dimensions of education. Humanistic education can no longer be viewed merely as a theoretical or elitist field, but rather as a framework for cultivating critical thinking, civic responsibility, and cultural empathy. Digital technologies, artificial intelligence, and new forms of communication are transforming both the content and the methods of teaching, creating the need for a dialogue between the humanities and the applied sciences. The university professor becomes a facilitator of learning and a mediator of meaning, while the student is encouraged to engage actively, reflectively, and creatively in the educational process. The transition of humanistic education also involves a reassessment of the fundamental values of the university: intellectual autonomy, academic freedom, and the formative role of culture. The reconceptualization of the university paradigm therefore does not imply abandoning the humanistic tradition, but rather reintegrating it into an open, collaborative, and future-oriented educational context. In this new framework, humanistic education remains essential for the development of an ethical, critical, and intercultural consciousness capable of responding to the challenges of contemporary society.

Keywords: Humanistic education; University paradigm; Educational transition; Critical thinking; Interdisciplinarity.

Introduction

Humanistic education, understood as a set of values, practices and ideals centered on the integral formation of man, is in a stage of profound redefinition. In recent decades, the acceleration of globalization, massive digitization and cultural fragmentation have substantially altered the meaning of university education and its relationship with classical humanism. The university, long considered a sanctuary of critical thinking and cultural reflection, is today challenged to rebuild its educational paradigm, between the pressures of the labor market and the imperatives of human development [1,2]. In a context dominated by epistemological uncertainty and axiological reconfigurations, the traditional paradigm of humanistic education

based on rationality, universality and the cultivation of critical spirit must be rethought in the light of a new educational reality. The transition to a postmodern paradigm of learning requires an interdisciplinary, dialogical and reflective approach, which emphasizes the relationship between knowledge, meaning and responsibility [3].

Thus, the reconceptualization of university humanistic education does not mean abandoning traditional values, but updating them in the light of the cultural, technological and ethical transformations of the contemporary world [4].

1. The Crisis of the Traditional Paradigm of Humanistic Education

Humanistic education has historically been the foundation of European university culture. Its ideal was the formation of the complete personality – rational, moral and aesthetic. However, in the post-industrial and digital age, this model has entered a structural crisis. Zygmunt Bauman [5] describes this situation as a "liquid modernity", in which values dissolve under the pressure of mobility and uncertainty.

In the university environment, the crisis manifests itself through the instrumentalization of knowledge and the orientation of education towards utilitarian skills, to the detriment of cultural and moral formation. Marta Nussbaum [6] warns that a society that neglects humanistic education loses its ability to support democracy, empathy and critical thinking. Romania is not spared by this trend. According to Marinescu [7], Romanian universities face "*a double pressure: adapting to the knowledge economy and preserving cultural identity*". This tension makes it necessary to rethink humanities education as a process of holistic training, not just professional training.

2. From Transmissive Teaching to Reflective and Collaborative Learning

The reform of the university paradigm involves a major epistemological mutation: the shift from transmissive teaching to reflective and collaborative learning. In the traditional paradigm, the teacher was the central source of knowledge, and the student a passive receiver. In the constructivist paradigm, knowledge becomes the result of social interaction and individual reflection [8,9].

Reflective learning emphasizes the inner processes of the student, interpretation, critical analysis and the integration of personal experiences into the construction of meaning. Models of learning based on projects, digital portfolios or action research represent modern strategies that stimulate autonomy and responsibility in academic formation [10].

In this vision, the teacher becomes a facilitator of learning an intellectual partner who guides the process of discovery. The pedagogical relationship is transformed into a reflective dialogue, in which meaning is constructed collaboratively. This transformation redefines the university ethos, replacing vertical authority with dialogue, and teaching with the co-creation of knowledge [11].

At the same time, digital education methods provide a new framework for developing reflective competencies. In online environments, collaborative learning becomes more accessible but also more complex, requiring new forms of responsibility and ethical discernment [12].

Contemporary transformations in education reflect a profound paradigm shift: the transition from a teacher-centered model, typical of the transmissive tradition, to a learner-centered model based on reflection, cooperation, and the active construction of knowledge. This article analyses

the theoretical foundations and practical implications of this transition, highlighting the role of new pedagogical approaches in developing students' reflective and collaborative competencies.

Contemporary education faces multiple challenges, driven by rapid changes in social, technological, and cultural spheres. In this context, the traditional transmissive teaching model based on the one-way transfer of knowledge from teacher to student proves its limitations. The student can no longer be conceived as a mere receptacle of information, but rather as an active agent in their own formation, engaged in a continuous process of reflection, analysis, and collaboration. This paradigm shift marks the transition toward reflective and collaborative learning, aimed at developing critical thinking, metacognitive skills, and teamwork abilities all essential competencies for integration into the knowledge society.

3. Transmissive Teaching: Characteristics and Limitations

The transmissive model of teaching has its roots in the tradition of classical pedagogy, centered on the teacher's authority and on knowledge as a finite object to be transmitted to the student.

From this perspective:

- The teacher is the possessor of truth and information.
- The student is a passive receiver, whose task is to reproduce content.
- The learning process is linear and reproductive, oriented toward memorization and summative evaluation.
- Communication is unidirectional, lacking interactivity.

Over time, this approach has led to a fragmentation of the learning experience and a decrease in students' intrinsic motivation. Numerous authors [13,14,15] have criticized this model, emphasizing its "banking" nature and the absence of a critical dimension in learning.

4. Reflective Learning: Between Critical Thinking and Self-Formation

The concept of reflective learning has its roots in the works of John Dewey and Donald Schön, who promoted reflection as an essential instrument for professional and personal development.

In this model:

- Learning involves self-regulation and awareness.
- The student becomes an active participant, capable of analysing, interpreting, and reconstructing knowledge.
- The teacher becomes a facilitator, mentor, or guide in the discovery process.

Reflective learning fosters critical thinking and metacognitive development through reflective journals, portfolios, case studies, and problem-based projects. Moreover, the focus shifts from immediate performance to the formation of long-term competencies.

5. Collaborative Learning: From Interaction to the Co-Construction of Knowledge

Collaborative learning is based on the idea that social interaction is an essential condition of the learning process. Inspired by the theories of social constructivism [16], it promotes cooperation, dialogue, and the negotiation of meaning among participants.

The central elements of collaborative learning are:

- Teamwork and shared responsibility for group outcomes.

- Open communication and constructive feedback.
- Positive interdependence, where each member's success contributes to the success of the entire group.
- The development of socio-emotional competencies: empathy, active listening, and conflict management. Thus, collaborative learning is not merely a teaching method, but a framework for personal and community development, contributing to the creation of a culture of cooperation and mutual respect.

6. The Role of the Teacher in the New Educational Model

The transition from transmissive teaching to reflective and collaborative learning entails a redefinition of the teacher's role. The teacher becomes:

- A designer of learning experiences, able to create meaningful and authentic contexts.
- A mediator of knowledge, who stimulates reflection and dialogue.
- A formative evaluator, who uses constructive feedback and continuous assessment.
- A lifelong learner, engaged in their own professional development.

In this sense, both initial and continuing teacher education must include reflective, collaborative, and digital dimensions to support the transformation of education toward a participatory pedagogy. The shift from transmissive teaching to reflective and collaborative learning represents not merely a methodological change but a cultural revolution in education. It entails a new vision of knowledge, of the teacher's role, and of the student's status, aligned with the values of a society based on lifelong learning and intercultural dialogue.

The education of the future can no longer be conceived in terms of information transfer, but as a reflective, dynamic, and collaborative process in which all educational actors actively participate in constructing meaning and developing a world founded on cooperation and shared responsibility.

7. The Ethical and Cultural Dimension of University Education

Humanistic education is not limited to the formation of intellectual skills but includes an essential ethical dimension. Habermas [17] argues that communicative rationality must underpin every educational process, since the goal of education is the formation of moral consciousness and a democratic spirit.

In a world dominated by algorithms and technological efficiency, the university must remain a space for moral reflection and intercultural dialogue. As Sălăvăstru [18] points out, the university bears a double responsibility: the development of professional competencies and the cultivation of civic spirit. In this sense, humanistic education becomes a project of moral and cultural accountability. It must promote values such as human dignity, solidarity, respect for diversity, and social responsibility. In a world increasingly dominated by algorithms and technological efficiency, the university must remain a space for moral reflection and intercultural dialogue. In this regard, humanistic education becomes a project of moral and cultural accountability. It should promote values such as human dignity, solidarity, respect for diversity, and social responsibility.

In the context of globalization, these are no longer mere abstract ideals but conditions for cultural survival [19,20]. A concrete example can be found in the growing emphasis within Romanian universities on courses in professional ethics, intercultural education, and applied

philosophy courses that seek not only to transmit knowledge but also to foster reflective and ethical consciousness [21].

8. Humanistic Education and the Challenges of Digitalization

The digital revolution has profoundly reshaped the academic landscape. Access to virtual resources, artificial intelligence, and technology-assisted learning provides enormous opportunities, but also poses significant risks. Lucian Floridi [22] refers to “digital humanism” as a paradigm that aims to reconcile technological development with humanistic values. For the university, this entails adapting curricula and teaching methods to contemporary realities without losing their axiological orientation. As Bîrzea [23] emphasizes, digital education should be viewed as “*an extension of humanism, not its replacement.*” Toma [24] further notes that while the virtual environment fosters more flexible and personalized learning, it may also diminish dialogical and reflective dimensions if not grounded in a robust ethical framework. In this respect, universities have a duty to promote critical digital literacy encompassing not only technical skills but also moral reflection and epistemological discernment. The advent of artificial intelligence in education introduces a new range of ethical and pedagogical dilemmas. Rather than perceiving AI as a threat, it can be harnessed as a tool to support reflective learning, provided it is guided by humanistic values used for emancipation, not control [25].

9. Reconceptualizing University Humanism within the Postmodern Paradigm

Reconceptualizing university humanism involves transcending the traditional dichotomy between the “hard” sciences and the humanities. In the contemporary university, disciplinary boundaries have become increasingly permeable, and dialogue across fields has emerged as a precondition for innovation. Humanistic education is no longer confined to the study of literature, philosophy, or history, but extends to critical reflection on the meaning of technology, communication, and the ethics of science [26].

Within this integrative paradigm, students are shaped not merely as specialists but as reflective individuals capable of linking scientific knowledge with human values. The teaching–learning process thus acquires a cultural and social dimension, becoming a means of reconstructing meaning in a fragmented world [27]. Consequently, university humanism is evolving into a relational humanism one grounded in dialogue, empathy, and the co-creation of meaning. This emerging model unites the scientific, ethical, and spiritual dimensions of education within a paradigm centred on the holistic development of the human being [28,29].

Conclusions

Humanistic education today stands at the crossroads of tradition and innovation. The transition toward a new university paradigm entails a complex process of reconceptualization aimed at redefining the meaning of knowledge, the role of the teacher, and the very identity of the university. In the digital age, rehumanizing education does not imply a nostalgic return to the past, but rather a renewal of humanistic values through technology and emerging forms of communication. The university of the future must serve as a space for critical reflection, intercultural dialogue, and ethical responsibility. As Dewey [30] reminds us, education is “*a mode of associated living.*”

Reconceptualizing the university paradigm in a humanistic sense thus requires rediscovering the communal dimension of learning where teachers and students become co-authors of their own intellectual and moral growth. The present analysis highlights the fact that humanistic education is undergoing a profound process of redefinition, driven by the technological, social, and cultural transformations of contemporary society. The transition toward a new university paradigm does not imply abandoning the humanistic tradition but rather reinterpreting it in a manner adapted to the demands of the digital age. In this context, reconceptualizing the role of the university becomes essential for reaffirming its formative mission, beyond the mere transmission of technical or professional skills.

The re-humanization of education thus emerges as an integrative endeavour aimed at fostering critical thinking, ethical awareness, and intercultural dialogue. Technology, far from representing an obstacle, can become a catalyst for humanizing the educational process, provided it is embedded within a pedagogical framework centered on the individual and on the educational relationship. In this regard, Dewey's conception of education as a "mode of associated living" gains renewed relevance, emphasizing the importance of the communal and collaborative dimensions of learning. Consequently, the contemporary university is called upon to assume its role as a space for critical reflection, social responsibility, and the holistic development of the individual. Reconstructing the university paradigm from a humanistic perspective entails not only curricular or methodological adjustments, but also a fundamental shift in the understanding of the meaning of education, in which teachers and students become co-participants in an ongoing process of knowledge construction and value formation. Such an orientation represents an essential condition for the relevance and sustainability of higher education today.

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THE IMPACT OF DIGITIZATION ON THE LEGAL PROTECTION OF PERSONAL DATA

Associate Professor Oana Voica NAGY Ph.D.

"Dimitrie Cantemir" University of Târgu Mureș, Faculty of Law, Romania
Corresponding author: Oana Voica Nagy: gugaoana@yahoo.com

Abstract

The processing, storage, and collection of personal data have been significantly transformed by rapid technological advancements, which have reshaped the ways in which individuals' information is managed, accessed, and utilized. The widespread adoption of digital platforms, cloud computing, and artificial intelligence has facilitated the growth of online services, enhanced administrative efficiency, and enabled innovative economic models. At the same time, these developments have substantially increased risks related to the confidentiality, integrity, and security of personal data, exposing both individuals and organizations to potential breaches, misuse, or unauthorized disclosure. Digitalization thus presents complex legal and ethical challenges for the protection of the right to privacy, a fundamental right guaranteed by Article 8 of the European Convention on Human Rights and reinforced by the Charter of Fundamental Rights of the European Union. This paper aims to provide a comprehensive examination of the current legal framework for data protection at both the European and national levels. At the European level, it focuses on Regulation (EU) 2016/679 – the General Data Protection Regulation (GDPR) – analyzing its principles, including lawfulness, fairness, transparency, purpose limitation, data minimization, and accountability. At the national level, particular attention is given to Romanian legislation implementing the GDPR and addressing sector-specific obligations. The study explores the practical challenges faced by data controllers and processors in complying with these legal obligations, including issues related to consent management, data subject rights, and the deployment of technologies such as the artificial intelligence. Furthermore, the paper investigates the role of supervisory authorities in monitoring compliance, enforcing sanctions, and providing guidance to both public and private actors. By evaluating the implementation of legal provisions and identifying the risks generated by new technologies, the study proposes measures aimed at strengthening data protection frameworks and ensuring that the fundamental right to privacy is respected in the digital era.

Keywords: digitalization, artificial intelligence, personal data, right to privacy, GDPR

1. General Aspects Regarding Digitalization

The rapid acceleration of technological development and innovations in the field of information technology have generated imbalances between the volume of personal data collected and used in the online environment and the legal provisions, as well as the measures and means available to the competent authorities for their protection.

In order to identify and understand the effect that digitalization has on human rights in general, and on the protection of personal data in particular, it is necessary to begin our analysis

by explaining this process, as well as the notion of personal data. The fast-paced development of technology has led to the transfer of numerous procedures and operations of various kinds into the virtual space, aimed at facilitating individuals' access to goods and services, whether public or private. Thus, with the help of digital applications and platforms, operations ranging from the simplest, such as online purchases, to the most complex economic, administrative, or judicial activities have become accessible to everyone. The use of these automated means has made personal data more vulnerable, exposing it to the risk of being accessed by unauthorized third parties.

Even central and local administrative-territorial authorities have been compelled, in the context of globalization, to offer citizens the possibility of accessing public services through digital platforms and applications. All these developments determined the need to increase the level of security, as well as the corresponding measures, due to the growth in the volume and types of data collected and stored through digital technologies.

Another direction in the development and implementation of digitalization is represented by social networks, which have spread rapidly, especially among young people. Social networks collect and analyze the data provided by users in order to determine their preferences, influence their behavior, and encourage them to follow certain trends through advertising. Young people belong to the category of vulnerable persons, whose discernment is still developing; therefore, they tend to attach much less importance to the protection of the data they provide when accessing social networks, websites, or when creating accounts on these applications.

The number of facilities available to individuals has increased exponentially with the spread of online data storage possibilities, as well as due to the increasingly frequent use of artificial intelligence. This context has led to the need for rigorous regulation of the protection of persons, their rights in general, and personal data as a fundamental right in particular.

From a strictly linguistic perspective, digitalization, according to the Romanian Explanatory Dictionary (DEX) [1], involves the transformation of analog signals into digital signals. From a technical point of view, however, this process involves converting documents and information from physical format into digital format so that they can be used in the virtual environment. This information can be collected, stored, and processed through various procedures. The operations listed are defined at the European level by Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 [2]. At national level, the provisions of the afore-mentioned regulation were adopted and transposed by the legislator into the provisions of Law no. 190/2018 [3].

2. Personal Data. Definition, Regulation and Case Law

Due to the major importance of the right to the protection of personal data of individuals, numerous national and international legal instruments regulate it as a fundamental human right. From a historical perspective, the right to the protection of personal data was regulated as early as 1950, with the adoption of the European Convention on Human Rights, in Article 8 [4]. Although it is not expressly provided as a distinct right within this article, the European Court of Human Rights has repeatedly emphasized in its case law that the protection of personal data falls within the scope of the right to respect for private and family life, home, and correspondence.

For example, the Grand Chamber of the European Court of Human Rights stated that “the mere recording of data relating to an individual’s private life constitutes an interference within the meaning of Article 8 of the European Convention on Human Rights,” and that it is necessary

to analyze, on a case-by-case basis, how such personal information is collected, stored, and processed, and whether this constitutes an infringement of the right provided for in the aforementioned article. Consequently, the Court has adopted different positions in different cases. Thus, in the case of *Uzun v. Germany*, the Court established the existence of an interference by the authorities in the applicant's private life through the collection of personal data via GPS surveillance, but found no violation of Article 8 of the Convention due to the seriousness of the acts that led to the operation and which constituted a threat to national security [5].

On the other hand, in the case of *Malone v. the United Kingdom*, the Court found a violation of Article 8 by the authorities through the recording and counting of telephone calls, an operation that involves identifying the telephone numbers dialed by the applicant and also found that the information collected forms part of the right to private life. The justification for such a decision was based on the lack of legal regulations in this respect. In both cases, the Court found that personal information collected and processed through technological means falls within the sphere of protection offered to individuals by the Article 8 of the Convention [5].

At the level of the European Union, however, the protection of personal data benefits strict regulation and protection, being elevated to the rank of a fundamental human right [6]. Thus, the Charter of Fundamental Rights of the European Union, in Article 8, recognizes two prerogatives under this right. On the one hand, individuals have the right to the protection of their personal data, and on the other hand, the right of access to all personal data that have been collected. In the latter case, individuals may request the rectification of collected data if they were improperly collected or have changed since the date of collection [7].

The Council of Europe, together with the European Union Agency for Fundamental Rights, has developed a *Handbook on European Data Protection Law*, which defines the notions related to the operations through which personal data are collected, processed, and stored, the general principles underlying the legal provisions in this field, and the interaction of this right with other fundamental rights. It also analyzes the challenges faced by the field of personal data protection, as well as the procedures for ensuring the protection of this right [8].

According to Regulation (EU) 2016/679, personal data means any information relating to an identified or identifiable natural person, whether identified directly or indirectly through a specific element. Article 4 align. (1) of the regulation indicates as identifying elements a person's name, location, an identification number assigned by public authorities, as well as other specific elements related to their physical, psychological, genetic, cultural identity, or similar aspects [2]. Regarding identification numbers, at national level this is defined by Article 2 letter (b) of Law no. 190/2018, according to which such numbers may lead to the identification of a natural person in various record systems, being characteristic of a driving license, identity card, passport, social health insurance, or personal numerical code [3].

Provisions regarding the protection of personal data are also found in the Civil Code, which, on the one hand, establishes name, domicile, and civil status as elements of identification of a natural person, regulating them in Chapter III of Book I, and, on the other hand, regulates this right as part of the category of personality rights recognized for natural persons [9].

The principles underlying the collection and processing of personal data are regulated by Article 5 of Regulation (EU) 2016/679, which provides a coherent and concrete framework. The three pillars that should underlie operations involving personal data are lawfulness, fairness, and transparency. The same article further highlights limitations related to the purpose of data collection and storage, data accuracy, as well as data integrity and confidentiality. Operators therefore have the obligation, and at the same time face the challenge, of protecting

such data against loss, damage, or destruction, and of detecting unauthorized and unlawful processing [2].

3. Conclusions

Globalization and the massive and rapid digitalization of recent years have led to the need to establish a rigorous legislative framework to protect natural persons against the unauthorized use of strictly personal information. Consequently, international bodies have intervened at all levels to develop regulations and manuals aimed at ensuring adequate protection of this fundamental right. However, these regulations must be implemented through effective security mechanisms.

Continuous innovation in the field of information technology also determines the need for constant improvement of legal provisions and the above-mentioned mechanisms, as well as the education of users in order to limit their own exposure in the online environment by providing personal data. It is also necessary to raise awareness among individuals regarding the risks and effects associated with giving consent for the collection, processing, and storage of personal data.

When analyzing the impact of digitalization on this fundamental right, the close connection between rights must also be considered, namely between the right to the protection of personal data and the right to private life, the relationship between them being, as shown by the case law of the European Court of Human Rights, that of a whole and a part. Bad faith in the collection and processing of information plays an important role in this regard, leading to violations of intimacy, private life, and family life.

On the other hand, as highlighted in the *Handbook on European Data Protection Law*, corporations may be influenced in decision-making regarding employees due to information obtained through the processing of personal data. Such data may be sensitive in nature, for example relating to health status, financial situation, or family circumstances [8].

Artificial intelligence represents an increasing danger, because it is commonly used to identify consumers' behavior, a procedure which also involves the collection and processing of a large amount of confidential personal information. In conclusion, digitalization, and especially technological evolution, will continue to generate situations that endanger the sensitive information of natural persons, making them vulnerable to abuse.

Therefore, constant updating of national, European, and international legislation is necessary, as well as the protection of measures for personal data. Data operators are required to adapt to technological evolution and to implement means to counter unauthorized and unlawful uses of the data they collect, process, and store.

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REFLECTIONS ON THE RECENT AMENDMENTS INTRODUCED BY LAW NO. 299/2024 TO LAW NO. 31/1990 ON COMMERCIAL COMPANIES

Associate Professor Ioana Raluca TONCEAN-LUIERAN Ph.D.

"Dimitrie Cantemir" University of Târgu Mureș, Faculty of Law, Romania
Corresponding author: Ioana Raluca Toncean-Luieran: tonceanioana@yahoo.com

Abstract

The present paper analyses the main amendments introduced by Law No. 299/2024 on the Amendment and Completion of Law No. 31/1990 on Commercial Companies, a legislative act that modernizes the framework of Romanian commercial companies. The new law aims to simplify formalities, enhance flexibility in corporate governance, and align national legislation with the current digital and economic realities. Among the most relevant changes are the elimination of the obligation to include information on beneficial owners in the constitutive act, the delegation of powers concerning the establishment and dissolution of secondary offices, the possibility to amend the general meeting's convening notice, and the introduction of electronic participation and voting mechanisms. These modifications reflect the legislator's intention to reduce bureaucracy, protect personal data, and increase transparency and efficiency in corporate decision-making. The paper also provides a critical perspective on the potential benefits and challenges resulting from the implementation of the new provisions, emphasizing their impact on the management and operation of commercial companies in Romania.

Keywords: commercial companies, Law No. 299/2024, Law No. 31/1990, digitalization, corporate law

1. Legislative Context

Company Law No. 31/1990 constitutes the general regulatory framework governing companies intended for commercial activities, providing the necessary legal basis for the incorporation, organization, and operation of commercial companies [2]. For more than 30 years, this law has ensured legal stability and predictability; however, market dynamics and technological developments have required its continuous adaptation in order to respond to new economic and digital realities.

In this context, Law No. 299/2024 amending and supplementing Company Law No. 31/1990 aims at modernizing and flexibilizing the rules applicable to commercial companies. The newly introduced provisions seek to reduce excessive formalism, integrate digital mechanisms, and increase the efficiency of the decision-making process within companies.

Since its entry into force, Law No. 31/1990 has represented the primary normative source governing legal relations between shareholders or associates, the structure of management bodies, and the mechanisms for the functioning of commercial companies. Even in the context of its repeated amendments, certain provisions have remained rigid and excessively formalistic, being insufficiently adapted to contemporary realities. This is particularly the case with regard to articles of association, procedures for convening general meetings, and certain competences

of corporate management bodies. The lack of clear provisions has often compelled companies to resort to interpretative solutions or ineffective statutory clauses, undermining the legal certainty of adopted decisions.

Accordingly, Law No. 299/2024 was adopted to modernize Law No. 31/1990 by ensuring greater flexibility in corporate governance, through the reduction of unnecessary formalities, enhanced protection of personal data, increased managerial efficiency, and the introduction of digital participation in general meetings. Some of these aspects, such as the protection of personal data, are regarded as fundamental human prerogatives, forming part of the category of personality rights safeguarded by the legislator, including through the regulation of the individual's right to private life [3]. The present study aims to analyze the main legislative novelties and their impact on commercial companies, from a practical perspective concerning the application of new provisions.

2. Elimination of the Obligation to Include Beneficial Owners in the Articles of Association

One of the most significant amendments to Law No. 31/1990 concerns the elimination of the obligation to include information regarding beneficial owners and the manner of exercising control over the company in the articles of association. Through this legislative intervention, Law No. 299/2024 repealed Articles 7 letter f¹) and 8 letter k¹) of Law No. 31/1990, which regulated this obligation both at the time of incorporation and upon amendment of the articles of association.

As previously noted, the obligation to include beneficial owners in the articles of association was introduced by Law No. 265/2022, in order to align national legislation with European Union rules regarding the management of the Register of Beneficial Owners by the National Trade Register Office [5]. However, the inclusion of such information in the articles of association generated significant practical difficulties, given that this document is subject to publicity in the Trade Register. Consequently, it became a means of exposing sensitive personal data, a situation deemed unjustified in relation to the pursued objective. Moreover, any change in the company's control structure required the amendment of the articles of association, entailing additional administrative and financial burdens for the company.

Restricting public access to sensitive information is justified from the perspective of personal data protection and contributes to compliance with the principles established by Regulation (EU) 2016/679 (GDPR). At the same time, the preparation and amendment of the articles of association are genuinely simplified through the reduction of formalism, thus facilitating the efficient functioning of commercial companies.

In this context, it should be emphasized that the elimination of this obligation does not affect the legal regime applicable to beneficial owners, as their declaration remains separately regulated by the special legislation on the prevention and combating of money laundering (Law No. 129/2019 on the prevention and combating of money laundering and terrorist financing). Transparency regarding the control structure of companies is therefore preserved, being ensured through appropriate and proportionate mechanisms. This legislative amendment successfully reconciles the need for transparency with the protection of personal data and the efficiency of corporate activity, representing a balanced legislative approach.

3. Delegation of Powers Concerning the Establishment and Dissolution of Secondary Offices

Law No. 299/2024 revises Article 114 of Law No. 31/1990 by extending the competences of the management bodies of joint-stock companies. The authority to establish or dissolve secondary offices — such as branches, agencies, or representative offices — may be granted to the board of directors or, where applicable, to the directorate, provided that this possibility is stipulated in the articles of association or approved by a resolution of the extraordinary general meeting.

The strengthening of the role of management bodies in overseeing company activities is, in this case, subject to the will of the shareholders as expressed in the articles of association or through a resolution of the extraordinary general meeting, thereby maintaining a balance between flexibility and control.

It should be noted that, prior to this amendment, the establishment or dissolution of secondary offices fell exclusively within the competence of the extraordinary general meeting, which entailed rigid formal procedures, consuming considerable time and resources [4]. In practice, this limitation restricted companies' ability to respond promptly to territorial reorganization needs.

Currently, companies are able to adopt swift decisions regarding the expansion or contraction of their activities without compromising legal certainty. For instance, the opening of an agency in another locality can now be carried out promptly, without the need to convene the general meeting for each such decision.

4. Flexibilization of the Procedure for Convening and Amending the Notice of the General Meeting

Prior to the adoption of Law No. 299/2024, any modification of the agenda or of the essential elements of the notice convening the general meeting required the entire convening procedure to be repeated, thereby delaying the adoption of decisions within joint-stock companies. In practice, this rigidity adversely affected the efficiency of the decision-making process, particularly in companies with a large number of shareholders.

Given that speed and flexibility are essential for the proper functioning of commercial companies, Law No. 299/2024 amends the legal regime governing the convening of general meetings by supplementing Article 117¹ of Law No. 31/1990. In this respect, paragraph (2¹) is introduced, according to which “the board of directors may amend the notice after its publication, within a maximum of 15 days from the date of publication.” Furthermore, pursuant to the revised Article 117¹ (3), amendments to the notice must be published at least 10 days prior to the date of the general meeting. Thus, the flexibilization of the convening procedure and of the amendment of the notice is carried out in compliance with clear conditions regarding time limits and the manner of informing shareholders. At the same time, the obligation to comply with legal and statutory publicity requirements is maintained.

This legislative amendment has a positive impact on corporate operations, as it allows for the correction of material errors or supplementation of the agenda without affecting the validity of the general meeting.

5. Introduction of Electronic Participation and Voting in General Meetings

In response to the need for digitalization, Law No. 299/2024 introduces two new articles — Articles 125¹ and 195¹ — into Law No. 31/1990. According to these provisions, shareholders or associates may participate in and vote at general meetings by electronic means of remote communication. This possibility must be previously provided for in the articles of association or decided by an extraordinary general meeting, with the majority of votes held by the shareholders present or represented.

Prior to these amendments, general meetings were generally held at the company's registered office or at another location specified in the convening notice, although the articles of association could designate a different venue [1]. It should be noted that the possibility of participating in general meetings through electronic means was temporarily regulated by Emergency Ordinance No. 62/2020 during the state of emergency. Subsequently, companies introduced such possibilities through their articles of association; however, a clear legal basis ensuring the legality and certainty of the adopted resolutions was lacking. As a result, alternative solutions were limited or insufficiently regulated, generating legal uncertainty.

The new provisions have a significant impact on the exercise of corporate rights, as they facilitate the involvement of individuals who are not physically present at the location of the general meeting, thereby increasing shareholder participation. Moreover, the use of digital technologies can substantially reduce costs and accelerate the overall decision-making process.

Nevertheless, pursuant to the newly introduced Article 125¹ (2) of Law No. 31/1990, electronic voting must meet essential technical requirements ensuring the identification of participants, their effective participation and the continuous transmission of deliberations, the exercise of shareholders' right to address the meeting, and the expression of votes within the general meeting. These requirements are intended to facilitate the identification of shareholders, the subsequent verification of voting procedures, and the possibility for each shareholder to verify their expressed vote. In this respect, companies are required to establish clear and transparent procedures guaranteeing compliance with the principles of equal treatment and the protection of shareholders' rights. However, the application of the new provisions may also give rise to certain practical difficulties, as the rules are not sufficiently detailed and the concrete modalities for implementing digital procedures are not fully clarified, potentially leading to divergent practices. Consequently, companies must ensure that all measures comply with legal requirements in order to avoid the invalidation of adopted resolutions.

A crucial clarification introduced by Law No. 299/2024 is contained in Article 125¹(3), according to which “the resolutions adopted within the general meeting held under the conditions of paragraphs (1) and (2) shall be signed either by hand or by electronic signature, in accordance with the law.” Given that Law No. 31/1990 traditionally required written form and handwritten signatures for minutes and resolutions, the absence of such an explicit provision could have generated legal uncertainty regarding the use of electronic signatures. The new regulation confirms the possibility of using both handwritten and electronic signatures, subject to compliance with the relevant special legislation. This provision significantly strengthens the legal certainty of resolutions adopted by general meetings held through electronic means.

Conclusions

Law No. 299/2024 contributes to the adaptation of Law No. 31/1990 to contemporary economic and technological realities. Through the newly introduced regulations, procedures are simplified, personal data protection is enhanced, decision-making processes are made more efficient, and shareholder participation in corporate life is facilitated.

As a result, the normative framework has become more flexible and efficient, better suited to the needs of the business environment. Nevertheless, the application of these new provisions requires increased attention from commercial companies in order to ensure compliance with the principles of legality and legal certainty.

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TECHNICAL-SCIENTIFIC FINDINGS AND FORENSIC EXPERTISE

Associate Professor Nelu Dorinel POPA Ph.D.

"Dimitrie Cantemir" University of Târgu Mureș, Faculty of Law, Romania
Corresponding author: Nelu Dorinel Popa: popaneludorinel@yahoo.com

Abstract

In the course of criminal proceedings, in order to ascertain the truth, it may be necessary to clarify certain facts or circumstances by resorting to the knowledge of specialists. In such situations, the judicial authority may order a technical-scientific finding or, where appropriate, an expert opinion. Both technical-scientific findings and expert opinions are evidentiary procedures regulated by the Code of Criminal Procedure, which have both common features and particularities that distinguish them from each other. In order to order a technical-scientific finding or a forensic expert opinion, the judicial authority must conduct a thorough analysis of their necessity and usefulness, so as not to resort to the assistance of specialists unless they can contribute to clarifying facts or circumstances that are important to the case, i.e., to finding the truth. Criminal procedure law also provides for remedies in cases where the expertise remains incomplete or its conclusions are unsatisfactory: supplementary expertise or new expertise. The fact that, in the final assessment of the evidence, the judicial body is not obliged to give a solution in accordance with the conclusions of the specialist or expert, as well as the possibility of carrying out a supplementary expert opinion or a new expert opinion, highlights the freedom of the judicial bodies to assess the value of the evidence. In conclusion, judicial bodies will use technical and scientific findings and expertise whenever issues involving specialist knowledge arise in criminal proceedings. An uncertain conclusion on a matter, based on examination by specialists, is preferable to total obscurity on that issue.

Keywords: technical-scientific findings, expertise, report, criminalist specialist, criminalist expert, procedural remedies.

Introduction

In the course of criminal proceedings, in order to ascertain the truth, it may be necessary to clarify certain facts or circumstances by resorting to the knowledge of specialists. In such situations, the judicial authority may order a *technical-scientific finding* or, where appropriate, an *expert opinion*.

Research Methodology

The research into these two evidentiary procedures regulated by the Code of Criminal Procedure and used in criminalistics began by highlighting both the common features and the specific characteristics of each of these procedures.

Brief considerations were then presented regarding the status of the forensic specialist/expert and the process of appointing them, the ordering, organization, and performance of the

investigation/expert examination, as well as the expert examination/technical-scientific investigation report.

The research continued with a presentation of the procedural remedies specific to the two evidentiary procedures, and the article concluded with several conclusions related to their final assessment.

Research Results

In terms of common features, we note that both technical-scientific findings and expert opinions are evidentiary procedures regulated by the Code of Criminal Procedure, i.e., ways of operating on certain material means of evidence whose use would not be possible without precise knowledge of their probative value. With their help, the conclusiveness of the traces contained or carried by objects or found on the body of the victim or suspect is established, as well as the probative value of the objects (instruments, material substances, etc.) that were used or intended to be used in the commission of the crime or of the objects that are products of the crime.

Just like other means of evidence, the evidence brought to light by the above procedures are extra-procedural entities, but these procedures acquire, like the evidence itself, the character of legal-criminal categories [1].

In order to order technical-scientific findings or expert reports, the judicial authority must conduct a thorough analysis of their necessity and usefulness, so as not to resort to the assistance of specialists unless they can contribute to clarifying facts or circumstances that are important to the case, i.e., to finding the truth.

This analysis is all the more necessary as many issues in the case can be clarified by other activities, such as hearing witnesses, suspects, and injured parties, reconstructions, confrontations, verifications, and seizures of documents, etc.

Also, in order to ensure the scientific evaluation of traces and material evidence through technical and scientific findings and expert reports, the judicial body must be familiar with and analyze all the material in the case file and only on this basis decide on the necessity and usefulness of resorting to specialists [2].

As a common element of the two evidentiary procedures, we add that, in principle, the arrangement of technical-scientific findings and expert opinions involves the same preparatory activities, and their performance involves the same working methods and techniques.

However, there are *particularities* that distinguish these evidentiary procedures, which we will refer to below. Thus, according to Article 172(9) of the Criminal Procedure Code, "when there is a risk of evidence disappearing or of factual situations changing, or when it is necessary to urgently clarify certain facts or circumstances of the case, the criminal investigation body may order an *investigation* to be carried out."

Therefore, a technical-scientific finding may be ordered only in three expressly regulated situations:

- when there is a risk of evidence disappearing;
- when there is a risk of factual situations changing;
- when it is necessary to urgently clarify facts or circumstances of the case.

In the first two situations, where a danger is invoked, it was considered that the judicial authority has the possibility to remove that danger, and if this is done, then no technical-scientific finding will be ordered. In such a situation, the judicial body has the obligation to take

the necessary measures to preserve traces, collect material objects, etc. In the third case, there is an urgent need to clarify certain facts or circumstances of the case [3].

The practice of judicial bodies has shown that both the risk of evidence disappearing and the danger of factual situations changing can be due to objective and subjective factors.

Objective factors include the effects of atmospheric agents, the alteration of traces or objects due to their chemical or physical properties, while *subjective factors* are represented by human activity, which may consist of voluntary intervention by participants in the commission of the crime or involuntary interventions by other persons [2]

In relation to these aspects, it has been assessed in the specialist literature that a technical-scientific finding can only be made in situations expressly provided for by the legislator, determined by the urgency with which action must be taken, and from the *a contrario* interpretation of the provisions invoked, it follows that, in all other situations, an *expert opinion* shall be ordered [4].

However, the Code of Criminal Procedure also makes some distinctions regarding the situations in which an expert opinion may be ordered, in addition to the interpretation in the doctrine mentioned above.

Thus, according to Article 172(12) of the Code of Criminal Procedure, "after the completion of the report, when the judicial authority considers that the opinion of an expert is necessary or when the conclusions of the report are contested, an *expert opinion* shall be ordered."

Furthermore, "an expert opinion shall be ordered when, in order to ascertain, clarify, or evaluate facts or circumstances that are important for establishing the truth in the case, the opinion of an expert is also necessary" [Article 172(1) of the Criminal Procedure Code].

In light of the aforementioned legal provisions and the ideas expressed, it can be concluded that the mere conduct of criminal proceedings is not sufficient to justify the urgency of ordering a technical-scientific assessment, so that even in the three situations where *an assessment* is nevertheless *ordered, this must be accompanied by an expert opinion*; this is all the more necessary if the technical-scientific report is contested or if the judicial authority specifically requests an expert opinion.

The main argument is that the expert opinion provides a set of additional procedural guarantees in favor of the injured party, the civil party, and the civilly liable party, as well as in favor of the suspect (the right to appoint an expert as a party, the possibility of challenging the conclusions of the expert report, etc.).

Another argument that could be added to this conclusion would be the use of the conjunction "and" in the afore-mentioned text of the law (when it states "the opinion of an expert is also required"), which indicates that this expertise follows something else and is not unique, implicitly referring to the technical-scientific finding.

A scientific argument can also be added, according to which the transition from technical-scientific findings to expertise implies a transition from the possibility of knowledge to knowledge itself, which can only be verified with the help of technical-scientific means provided by science [2]; in practice, this implies a perfection of knowledge.

In light of these arguments, it can be concluded that conducting an expert assessment during criminal proceedings should be the rule, and ordering a technical-scientific finding should be an exceptional situation, determined by the urgency with which a piece of evidence must be administered, the clarification of a factual situation, or the clarification of circumstances of the case. A contrary situation could lead to a violation of the procedural rights of the parties or the main subjects of the proceedings, which could lead to the annulment of a technical-scientific report, if one exists [4].

Also, with regard to *technical-scientific findings*, we note that, in accordance with the provisions of Article 172(11) of the Criminal Procedure Code, "the forensic medical certificate has the value of a finding report," which indicates that forensic medical findings have the same legal status as technical-scientific findings.

Furthermore, as a common denominator of the two types of findings, we also point out that the judicial authority or the parties cannot intervene in the course of either of them.

A particular feature of the forensic finding is that the competent forensic body, having at its disposal the corpse or the persons to be examined, does not usually need to request data from the judicial bodies [1].

From the point of view of the person competent to carry out a technical-scientific examination, according to Article 172(10) of the Criminal Procedure Code, "the examination shall be carried out by a specialist working within or outside the judicial authorities." Furthermore, the forensic specialist who performs the technical-scientific finding cannot be delegated and cannot assume the powers of a criminal investigation body [5].

According to Art. 174 para. (5) in relation to Art. 172 para. (10) of the Criminal Procedure Code, the provisions regarding the incompatibility of the expert also apply to the forensic specialist conducting the technical-scientific investigation. Furthermore, if there is any case of incompatibility, the forensic specialist appointed to carry out the technical-scientific investigation is obliged to notify the criminal investigation body as soon as he becomes aware of this. The abstention or recusal of the forensic specialist shall be resolved in accordance with the procedure provided for in Article 69 of the Criminal Procedure Code, falling within the competence of the prosecutor conducting the criminal investigation.

With regard to the subject matter of the investigation and the investigation report, Article 181¹ of the Criminal Procedure Code provides that "the criminal investigation body shall determine by order the subject matter of the investigation, the questions to be answered by the specialist, and the time limit within which the work is to be carried out. The report on the findings shall include a description of the operations carried out by the specialist, the methods, programs, and equipment used, and the conclusions of the findings."

On the other hand, with regard to *forensic expertise*, general clarifications need to be made, specific to all types of expertise and, implicitly, to forensic expertise.

According to the rules of criminal procedure mentioned below in Article 172 of the Criminal Procedure Code, paragraphs (2)-(8) [in addition to the provisions of paragraph (1), referred to above], regarding the ordering of expert examinations, it is stipulated that "expertise shall be ordered, under the conditions of Article 100 (relating to the administration of evidence), upon request or ex officio, by the criminal investigation body, by means of a reasoned order, and during the trial it shall be ordered by the court, by means of a reasoned decision.

The request for an expert opinion must be made in writing, indicating the facts and circumstances to be assessed and the issues to be clarified by the expert.

The expert examination may be carried out by official experts from laboratories or specialized institutions or by authorized independent experts from within the country or abroad, in accordance with the law.

The expert examination and forensic examination shall be carried out within forensic institutions.

The order of the criminal investigation body or the court decision ordering the expert assessment must indicate the facts or circumstances that the expert must ascertain, clarify, and evaluate, the objectives to be met, the deadline for the expert assessment, and the designated institution or experts.

In highly specialized fields, if specific knowledge or other similar knowledge is necessary to understand the evidence, the court or the criminal investigation body may request the opinion of specialists working within or outside the judicial bodies. The provisions relating to the hearing of witnesses shall apply accordingly.

Independent authorized experts appointed at the request of the parties or the main subjects of the proceedings may participate in the expert examination.

The request, ordering, and performance of an expert examination constitutes a procedural (evidentiary) activity that involves the active presence of procedural bodies and subjects. The procedural measure of the expert examination is carried out by performing a set of procedural and procedural acts, some of which are the responsibility of the judicial bodies (official subjects), and others of the parties (main subjects of the criminal proceedings) and occasional procedural subjects (experts) [1].

As a rule, in order to order an expert examination, the judicial body must find that certain facts or circumstances of the case are not sufficiently clarified and that the knowledge of a specialist is necessary to clarify them. These conditions must be met cumulatively, as the mere existence of unclear facts or circumstances does not necessarily imply the use of experts; these may be clarified on the basis of the evidence to be administered or on the basis of the general knowledge possessed by the judicial authorities.

In Romania, the status of judicial experts and the organization of judicial expertise are regulated by two normative acts, namely *Ordinance No. 2/2000 on the organization of judicial and extrajudicial technical expertise, together with Ordinance No. 75/2000 on the organization of forensic expertise*. These normative acts define the status of judicial experts (technical and forensic) and therefore regulate the status of this judicial subject [6].

There is no specific law that separately regulates the status of forensic experts and forensic expertise in the new realities and conditions, which are essential aspects in the field of forensic science and have been long awaited.

Instead, under current regulations, the forensic expert is regulated sporadically and insufficiently, having, in turn, the status of:

- *official expert*, according to the Criminal Procedure Code, appointed by the judicial authority in a criminal or civil case;
- *a procedural subject*, according to Article 33 of the Criminal Procedure Code;
- *a regulated profession*, requiring a minimum of three years of higher education, authorized by the Ministry of Justice, according to Annex 2, point A) letter v) of Law No. 200/2004;
- *an occupation* mentioned in the List of occupations practiced within the national economy of Romania, with code 261902, regulated by Order of the Ministry of Labor No. 1832/856/2011;
- *civil servant*, employee of the National Institute of Forensic Science within the Ministry of Justice, in accordance with Government Decision No. 368/1998;
- *specialist staff* working in public institutes or in public or private specialist laboratories;
- *employee of the Romanian Police* within the criminal investigation structures and drug and narcotics analysis laboratories, according to Law No. 218/2002 and I.G.P.R. Order No. 131/2012 (Necula, 2020).

With regard to *the appointment of the expert*, as stated in Article 173 of the Criminal Procedure Code, "the expert shall be appointed by order of the criminal investigation body or by court decision.

The criminal investigation body or the court shall, as a rule, appoint a single expert, except in cases where, due to the complexity of the expertise, specialized knowledge from different disciplines is required, in which case two or more experts shall be appointed.

When the expertise is to be carried out by a forensic institution, institute, or specialized laboratory, the appointment of one or more experts is made by that institution, in accordance with the law.

The parties and the main subjects of the proceedings have the right to request that an expert recommended by them participate in the expert examination. If the expert examination is ordered by the court, the prosecutor may request that an expert recommended by him participate in the expert examination.

The expert, the forensic institution, the specialized institute or laboratory may, at the request of the expert, request, when deemed necessary, the participation of specialists from other institutions or their opinion.

The forensic institution, institute, or specialized laboratory shall communicate the names of the appointed experts to the judicial body that ordered the expert examination.

An analysis of the text of the law shows that forensic expertise can be carried out, on the one hand, both within public forensic institutions by official experts and, on the other hand, within private forensic laboratories by authorized forensic experts.

The latter may effectively participate in the expert examination carried out by the official expert, who works within the respective public forensic institutions (institutes, laboratories, services).

However, the current reality is quite different, namely:

- the judicial authority prefers to call on official experts from public forensic institutions (inter-county laboratories within the National Institute of Forensic Expertise in under the Ministry of Justice, the National Institute of Forensic Science of the Romanian Police, and the forensic services within the county police inspectorates);
- the independent expert appointed by the parties may not participate in the forensic examination conducted by the official forensic expert within public institutions.
- Authorized independent forensic experts cannot carry out their activities in private forensic or judicial laboratories or in professional civil societies, because there is no legislation regulating this field and chambers of commerce do not approve their establishment.

It has been rightly noted in the specialist literature that, for these reasons, private forensic expertise in Romania is, to a large extent, a fiction, so that, in light of these arguments, it is necessary to adopt normative acts regulating the effective participation of authorized independent forensic experts in the official expert's expertise, the authorization of private forensic laboratories, and the establishment of the College of Forensic Experts (Popa, 2020).

Article 174 of the Criminal Procedure Code regulates *the incompatibility of experts and specialists*, stipulating that "a person in any of the cases of incompatibility provided for in Article 64 (regarding the incompatibility of judges) cannot be appointed as an expert, and if they have been appointed, the court decision cannot be based on their findings and conclusions. The reason for incompatibility must be proven by the person invoking it.

In the same case, a person cannot be both an expert appointed by the judicial authority and an expert recommended by one of the parties to the proceedings.

A person who works within the same forensic institution, institute, or specialized laboratory as the expert appointed by the management of that institution at the request of the judicial authority cannot be appointed as an expert recommended by the parties in the same case.

However, if there is any case of incompatibility, the expert is obliged to notify the criminal investigation authorities or the court as soon as he or she becomes aware of this. The abstention or recusal of the expert shall be resolved in accordance with the procedure provided for in Articles 68 and 69 of the Criminal Procedure Code, falling within the competence of the prosecutor conducting the criminal investigation (during the criminal investigation phase) or the council chamber of the court where the criminal case in which the expert was appointed to carry out the expert examination is pending (during the trial phase) [1].

The rights and obligations of the expert are regulated by Article 175 of the Criminal Procedure Code, according to which "the expert has the right to refuse to perform the expert examination for the same reasons that a witness may refuse to testify.

The expert has the right to examine the case file material necessary for the expert examination.

The expert may request clarification from the judicial body that ordered the expert examination regarding certain facts or circumstances of the case that need to be assessed.

The expert may request clarification from the parties and main subjects of the proceedings, with the approval and under the conditions established by the judicial authorities.

The expert is entitled to a fee for the work performed in order to carry out the expert assessment, for the expenses that he or she should incur or has incurred in order to carry out the expert assessment. The amount of the fee is determined by the judicial authorities depending on the nature and complexity of the case and the expenses incurred or to be incurred by the expert. If the expert opinion is carried out by the forensic institution or the specialized institute or laboratory, the cost of the expert opinion is determined under the conditions provided by the special law.

The expert may also benefit from protective measures under the conditions provided for in Article 125 (relating to threatened witnesses).

The expert is required to appear before the criminal investigation authorities or the court whenever summoned and to prepare the expert report within the deadline set in the order of the criminal investigation authority or in the court's decision. The deadline in the order or decision may be extended, at the expert's request, for valid reasons, without the total extension granted exceeding 6 months.

Unjustified delay or refusal to perform the expert assessment shall result in the application of a judicial fine, as well as civil liability of the expert or the institution designated to perform it for the damages caused.

The legislator has conferred several prerogatives on the forensic expert, probably as a corollary to certain correlative obligations, to which the above article refers.

In addition, following cases encountered in practice, legal doctrine has emphasized *the active role* of the forensic expert, viewed from several aspects, namely:

- a summary of all the actions they can take, by virtue of their attitude towards the work they do;
- the obligation to carry out investigations with the utmost responsibility, to take all necessary steps to ensure that examinations are conducted in accordance with the scientific criteria underlying identification, to provide the judicial authority with a well-founded and rigorously argued conclusion;
- to provide all the data they discover during the examination of the evidence, data which they consider to be useful to the case, even if it exceeds the objective set by the judicial authority;

- in terms of communication between the expert and the judicial body, the obligation to request explanations and/or clarifications from the judicial body in the event of confusing, ambiguous, or incomplete formulations of the objectives of the expertise, as well as the obligation to request the judicial body to reformulate the objectives when they are incorrectly formulated from the point of view of criminal identification.

In relation to these aspects of the active role of the forensic expert, it has been emphasized that, in a hypothetical antithesis between the active and passive roles of the expert, the former will be the positive character [8].

This conclusion is reinforced by another author, who admits the existence of special situations in which, for example, the task of obtaining comparison material (experimental shooting with a gun, taking fingerprints, etc.) falls to the forensic expert. These situations should be considered *exceptions* and are conditioned either by the need for specialized technical-criminalistic knowledge or by the existence of specialized equipment available only to criminalistic institutions.

As such, these situations only apply to the preparation of comparative material, as requested by the body requesting the expertise and only on the basis of the material indicated by that body, without the expert assuming the obligations of a judicial body [9].

The replacement of the expert is regulated by Article 176 of the Criminal Procedure Code, according to which "the expert may be replaced if he refuses or, without justification, fails to complete the expert report by the set deadline.

The replacement shall be ordered by the criminal investigation body or by the court, after summoning the expert, and shall be communicated to the association or professional body to which he belongs.

The expert shall also be replaced when his or her declaration of abstention or request for recusal is accepted or when he or she is objectively unable to perform or complete the expert assessment.

The replaced expert must, under the penalty provided for in Article 283(4) – judicial fine, immediately make available to the judicial body all the documents or objects entrusted to him, as well as his observations on the activities carried out until the moment of his replacement.

The procedure for conducting an expert examination is regulated by Article 177 of the Criminal Procedure Code: "When ordering an expert examination, the criminal investigation body or court shall set a date on which the parties, the main subjects of the proceedings, and the expert, if appointed, shall be summoned.

On the set date, the prosecutor, the parties, the main subjects of the proceedings and the expert shall be informed of the subject matter of the expert examination and the questions to be answered by the expert and thus, shall be informed that they have the right to comment on these questions and that they may request that they be amended or supplemented. Where appropriate, the expert shall also be informed of the objects to be examined.

The expert shall be informed that he or she is obliged to analyze the subject matter of the expert opinion, to accurately indicate any observations or findings, and to express an impartial opinion on the facts or circumstances assessed, in accordance with the rules of science and professional expertise.

The parties and main subjects of the proceedings are informed that they have the right to request the appointment of one expert recommended by each of them to participate in the expert examination.

After examining the objections and requests made by the parties, the main subjects of the proceedings, and the expert, the criminal investigation body or the court shall notify the expert

of the deadline by which the expertise is to be carried out, informing him at the same time whether the parties or the main subjects of the proceedings are to participate in its performance.

When the expert examination is to be carried out by a forensic medical institution, a forensic laboratory, or any specialized institute, the provisions of Article 173(3) shall apply, and the presence of the expert before the judicial authority shall not be required.

Therefore, based on the materials and data made available and the specialist knowledge they possess, the expert proceeds to carry out the actual expert examination, i.e., to investigate its objectives, using appropriate procedures, performing various technical or laboratory analyses and checks in order to obtain the elements necessary to resolve the issues raised by the expert examination, all of which constitute the content of the expert's work (Antoniou, 2003).

The practice of judicial bodies has shown that the value and quality of any expertise depend mainly on:

- strict compliance with the law when ordering the expertise;
- the correct determination of the subject matter of the expert opinion and the appropriate preparation by the judicial body ordering it of the materials necessary for the expert to prepare the report;
- the scientific nature of the examination methodology used by the expert and of the conclusions formulated [10].

With regard to *the expert report*, Article 178 of the Code of Criminal Procedure provides as follows: "After the expert examination has been carried out, the findings, clarifications, assessments, and opinion of the expert shall be recorded in a report.

When there are several experts, a single expert report shall be drawn up. Separate opinions shall be justified in the same report.

The expert report shall be submitted to the judicial authority that ordered the expert examination.

The expert report shall include:

- *-an introductory part*, indicating the judicial body that ordered the expert assessment, the date on which it was ordered, the expert's first and last name, the objectives to be addressed by the expert, the date on which it was carried out, the material on which the expert assessment was based, proof that the parties were notified, whether they participated in it and provided explanations during the expert examination, the date on which the expert report was drawn up;
- *-the expository part*, describing the operations involved in carrying out the expert assessment, the methods, programs, and equipment used;
- *-the conclusions*, which respond to the objectives set by the judicial authorities, as well as any other clarifications and findings resulting from the expert examination, in relation to the objectives of the expert examination. If the expert assessment was carried out in the absence of the parties or the main subjects of the proceedings, they or their lawyer shall be informed of the preparation of the expert report and of their right to study the report.

The conclusions of the expert report are not binding on the judicial authority, which verifies the conclusions of the expert report in relation to all the evidence administered in the case.

The result of the verification of the conclusions of the expert report may lead to the finding that there is perfect consistency between these conclusions, on the one hand, and the conclusions that can be drawn from the trial materials gathered during the criminal investigation or trial, on the other hand. In such a situation, the expert report is said to be *confirmed*.

However, the verification may result in the conclusions being rejected because the judicial authority's investigations have led to the discovery of new evidence that casts the previous data on which the expert report is based in a different light. At other times, verification of the expert report may lead to the finding that the persons responsible for carrying out the expert examination have acted in a manner inconsistent with their specialist knowledge or have not used the most appropriate methods and means to reach accurate and sound conclusions. In this case, the expert report and its conclusions will be *rejected*.

However, the conclusions of the experts should not be underestimated by the judicial authorities, nor should they be overestimated, because there is a possibility that, objectively speaking, due to insufficient materials or data made available to the experts or due to other causes not attributable to the expert, the expert may not be able to reach a conclusion that is satisfactory to the judicial authority [1].

It has also been argued in doctrine that the expert report is a means of evidence that does not have greater probative value than other means of evidence. However, due to its scientific nature, the conclusions of the expert report place this evidence in a superior position within the body of evidence. Considering that it is ordered by the judicial body and carried out by specialists who are recognised for the scientific nature of their analyses, the judicial expert report enjoys a privileged position, as long as it is not contradicted by other evidence.

The conclusions of such a report could be challenged in two ways:

- by demonstrating that the expert report contains conclusions that are irrelevant to the case, which is why they will not be taken into account by the judicial authority;
- obtaining an extrajudicial expert report, expert opinions, or witness statements that enjoy superior scientific recognition [7].

For greater accuracy of the conclusions of the expert report, *the expert may be heard*. Thus, according to Article 179 of the Criminal Procedure Code, "during the criminal investigation or trial, the expert may be heard by the criminal investigation body or the court, at the request of the prosecutor, the parties, the main subjects of the proceedings, or ex officio, if the judicial body considers that the hearing is necessary to clarify the expert's findings or conclusions.

If the expert examination was carried out by a forensic institution, institute, or specialized laboratory, the institution shall designate an expert from among the persons who participated in the expert examination to be heard by the criminal investigation body or the court.

The hearing of the expert shall be conducted in accordance with the provisions relating to the hearing of witnesses.

Criminal procedural law also provides for certain *remedies* in cases where the expert opinion remains incomplete or its conclusions are unsatisfactory: *a supplementary expert opinion or a new expert opinion*.

The supplementary expert opinion is regulated by Article 180 of the Criminal Procedure Code, according to which "when the criminal investigation body or the court finds, upon request or ex officio, that the expert opinion is incomplete and this deficiency cannot be remedied by hearing the expert, it shall order a supplementary expert opinion to be carried out by the same expert.

When it is not possible to appoint the same expert, another expert opinion shall be ordered to be carried out by another expert. When the expert opinion was carried out within a forensic institution, institute, or specialized laboratory, the criminal investigation body or court shall address the respective institution in order to carry out the supplementary expert opinion."

Article 181 of the Criminal Procedure Code provides some clarification regarding *the performance of a new expert examination*; according to this text of law, "the criminal

investigation body or the court shall order a new expert examination when the conclusions of the expert report are unclear or contradictory, or when there are contradictions between the content and the conclusions of the expert report, and these deficiencies cannot be remedied by hearing the expert.

When the criminal investigation body or the court orders a new expert examination to be carried out by a forensic institution, it shall be carried out by a commission, in accordance with the law."

The supplementary expert report, like the new expert report, shall be carried out in accordance with the same provisions as the first expert report. The main and occasional subjects shall have the same powers, duties, and prerogatives, and the new conclusions shall be subject to verification by the judicial authority in relation to all the evidence administered (Antoniou, 2003).

Conclusions

In conclusion, we note that in *the final assessment* of the evidence, the judicial body is not obliged to give a solution in accordance with the conclusions of the specialist or expert, as there is the possibility of conducting a supplementary or new expert assessment, which highlights the freedom of the judicial authorities to assess the value of the evidence [12].

In conclusion, we can also state that the judicial authorities will use technical and scientific findings and expertise whenever issues involving specialist knowledge arise in criminal proceedings. *An uncertain conclusion on a matter, based on examination by specialists, is preferable to total obscurity on that issue.* Before the judicial authorities order an expert opinion, it is advisable to examine the special provisions governing each category of expertise, as these provisions take precedence over the provisions of the Code of Criminal Procedure. Only where the special law does not provide otherwise shall the judicial authorities apply the Code of Criminal Procedure (Antoniou, 2003).

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THE CALCULATION OF THE NOTICE PERIOD IN THE CONTEXT OF ARTIFICIAL INTELLIGENCE USE

Lecturer Natalia SAHAROV Ph.D.

"Dimitrie Cantemir" University of Târgu Mureș, Faculty of Law, Romania
Corresponding author: Natalia Saharov: sanav2003@yahoo.com

Abstract

The article analyzes the legal regulations regarding the calculation of the notice period, within the framework of individual employment relationships regulated by the Labor Code, the non-unitary jurisprudence that called for the intervention of the ICCJ through Decision no. 8.2024 pronounced in resolving the appeal in the interest of the law, as well as the way in which artificial intelligence (AI) tools can be used in this process of calculating the notice period. The study proposes an interdisciplinary approach, combining the legal analysis of the legal provisions regarding the termination of the employment contract with the technical and ethical implications of the automation of administrative decisions. The main conclusion is that AI can contribute to making the process of regulatory compliance more efficient, but only to the extent that the principles of data protection, transparency and human control are respected.

Keywords: labour law, notice period, artificial intelligence, automation, data protection, legal compliance.

Introductory Considerations

The transformations generated by digitalization and the expansion of artificial intelligence profoundly influence the way human resources processes are managed, including those related to the termination of individual employment contracts.

One of the essential aspects of this procedure is the calculation of the notice period which, although apparently technical, has direct legal consequences on the validity of the termination act and on the protection of employees' rights.

The Legal Framework, Meaning, Justification and Duration of the "Notice Period"

Law no. 53/2003 – the Labour Code [1], republished, regulates the notice period under Article 75 in the case of dismissal and under Article 81 regarding resignation.

Doctrine defines the notice period, in the case of dismissal, as the written notification made by the employer to the employee, through which the latter is informed of the termination of the individual employment contract for reasons not related to the employee's person [2].

The employer's obligation to grant notice applies only where the termination of the individual employment contract is initiated by the employer. This means that where termination occurs as a result of the employee's fault (disciplinary misconduct or commission of criminal offences), the employer has no obligation to grant a notice period.

In the case of resignation, starting from the meaning of the term itself — termination of the individual employment contract at the initiative of the employee — the notice period is analysed as the employee's announcement of their intention to terminate the employment contract [3].

The legislator regulates the duration of the notice period separately for the two modes of termination of the individual employment contract, as follows:

- the notice period in the case of dismissal, pursuant to Article 61 letters c) and d), Articles 65 and 66, may not be less than 20 working days (Article 75 (1) of the Labour Code);

Given the explicit reference to the aforementioned legal provisions in Article 75 (1) of the Labour Code, the employer is obliged to notify employees who are to be dismissed due to physical or mental unfitness, as well as those dismissed for professional inadequacy or as a result of the reorganization of the enterprise.

For persons with disabilities, the notice period may not be less than 30 days (Article 83 letter e) of Law no. 448/2006, republished, on the protection and promotion of the rights of persons with disabilities).

- the notice period in the case of resignation may not exceed 20 working days for employees holding execution positions, and 45 working days for employees holding management positions (Article 81 (4) of the Labour Code)

From a legal perspective, the notice period has a dual nature: contractual and protective. It serves both the employer's interest, by allowing the organization of the work process, and the employee's interest, by providing a period of professional transition. Specifically, in the case of dismissal, the notice period constitutes a guarantee of the right to work and aims to avoid the negative consequences that could result from the employer's sudden unilateral termination of the employment contract. In the case of resignation, the notice period aims to protect the employer against the sudden termination of the employment contract at the employee's initiative, especially since such termination may occur, if done in bad faith, at moments when the employer most needs employees. The obligation to give notice first appeared in France, in circumstances where a group of employees hired to present a fashion designer's new collection resigned on the very day the presentation was to take place [4].

A dismissal ordered without granting the notice period or without respecting its minimum legal duration is subject to absolute nullity.

The duration of the notice period is provided as a mandatory element in the dismissal decision under Article 76 letter b) of the Labour Code.

The mandatory inclusion of this element in the dismissal decision has been critically analysed in legal doctrine, noting that "it is difficult to explain the rationale of this requirement given that the notice period, according to its very name, must be granted prior to dismissal and is established by the collective or individual employment contract" [5]. Thus, it has been considered that where the employer has in fact fulfilled, prior to issuing the dismissal decision, the obligation to grant the notice period, the decision is not subject to absolute nullity even if it does not specify the "duration of the notice period", an obligation imperatively imposed by the Labour Code [6]. This solution - apparently contrary to the imperative legal text - was justified by correlating the general principle of good faith underlying employment relationships with the principle of exercising rights only according to their economic and social purpose, thus not by way of abuse of rights [7]. The doctrinal debate was also supported by non-uniform case law.

By Decision no. 8/2014 of the High Court of Cassation and Justice – the panel competent to rule on appeals in the interest of the law, published in the Official Gazette of Romania, Part I, no. 138/24.02.2025, the issue was settled as follows:

- failure to grant the notice period of the minimum duration provided by Article 75 (1) of the Labour Code, or of the duration stipulated in collective or individual employment contracts if more favourable to the employee, entails the absolute nullity of the dismissal measure and the dismissal decision.
- the absence from the dismissal decision of the mention regarding the duration of the notice period granted to the employee is not sanctioned by nullity of the decision and of the dismissal measure where the employer proves that the employee was granted the notice period of the minimum duration provided by Article 75 (1) of the Labour Code or the duration provided in collective or individual employment contracts, where more favourable.

In case law [8], it has been stated that from a logical and grammatical interpretation of the legal text it results that the notion of “notice period” signifies a term, namely a time interval having a starting moment and an ending moment. Therefore, in order to respect both the letter and the spirit of Article 76 of the Labour Code, any decision based on Article 65 of the Labour Code must mention the notice period, namely its duration in days, the moment when it begins to run, and the moment when it ends. In this way, the court vested with solving a challenge against the dismissal decision has the effective possibility to verify whether the right to notice was indeed respected, that is, whether the employee effectively benefited from the number of working days constituting the alleged notice period.

The Calculation of the Notice Period

Although the legal rule appears clear, its concrete application involves numerous variables:

- the exact determination of working days depending on the individual work schedule;
- the suspension of the running of the notice period in cases of medical leave, unpaid leave, or other forms of justified absence. In this respect, Article 75 (3) of the Labour Code provides that where, during the notice period, the individual employment contract is suspended, the notice period shall be suspended accordingly, except for the case provided under Article 51(2);
- the existence of clauses in the individual or collective employment contract that may modify the duration of the notice period, within legal limits;
- situations of hybrid or remote work, which complicate the identification of days actually worked.

Thus, in practice, the calculation of the notice period is not free from administrative errors and generates litigation, especially in conditions of incomplete documentation or a mechanical interpretation of the law.

Moreover, prior to the publication of Decision no. 8/2024 of the High Court of Cassation and Justice – the panel competent to rule on appeals in the interest of the law [9], judicial practice lacked a uniform viewpoint regarding the method of calculating the notice period.

According to one line of case law, the day on which the notice was communicated and the day on which the term expired were not included in the calculation. According to another line, both the day of communication of the notice and the day on which the term expired were included.

Following the publication of Decision no. 8/2024 of the High Court of Cassation and Justice in the Official Gazette of Romania, Part I, the legal interpretation became mandatory, establishing that “the notice period begins to run on the day following the communication of the notice and is completed on the last day of the term”.

Artificial Intelligence in the Automation of Notice Period Calculation

In recent years, solutions based on artificial intelligence applied in human resources management have evolved significantly, allowing the automation of certain legal-administrative processes, including the calculation of the notice period. AI tools can be configured to apply codified legal rules, capable of interpreting relevant legal provisions, correlating data from timekeeping systems, and determining the effective duration of the notice period.

Such systems may:

- verify compliance with labour legislation and applicable collective agreements;
- automatically calculate the number of working days, excluding leave days or justified absences;
- generate legal alerts regarding statutory deadlines;
- contribute to the standardization of procedures in organizations with a large workforce.

However, these solutions must be accompanied by mechanisms of human control in order to avoid erroneous interpretations or mechanical application of legal rules. The calculation of the notice period, although seemingly simple, has generated frequent errors and non-uniform case law, which is why artificial intelligence cannot substitute the human factor.

The automation of a legal process raises additional issues. First, interpretation remains an eminently human activity, based on legal reasoning and contextualization, aspects difficult to replicate algorithmically. Given the special nature of labour law rules governing the notice period and its calculation - derogatory from the general rules of civil procedural law - the continuous presence of the human factor remains essential. Second, the use of AI must comply with the principles of personal data protection regulated by Regulation (EU) 2016/679 (GDPR) [10], considering that automated systems process data concerning employees' attendance, absences, or performance.

Finally, analysis is required in light of the fundamental principles of labour law:

- the principle of employee protection;
- the principle of good faith;
- the principle of equal treatment.

These principles may be affected if algorithmic decisions lack transparency or if there is no mechanism for human verification of the results generated by AI.

Conclusions

The implementation of artificial intelligence in the calculation of the notice period represents a natural development in the context of the digitalization of employment relationships, but also a challenge for legal scholars and practitioners.

Technological solutions can contribute to increased efficiency and reduced errors, provided that they are integrated within a clear legal framework ensuring transparency, accountability, and human control over the decision-making process.

In conclusion, artificial intelligence should not be viewed as a substitute for legal reasoning, but as a support tool in the correct and predictable application of labour law norms. The near future will require doctrinal and legislative adaptation to explicitly regulate the role of AI in administrative processes with legal relevance, including the calculation of the notice period.

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THE IMPACT OF GOVERNMENT EMERGENCY ORDINANCE NO. 62/2024 ON THE ACT OF JUSTICE AND ON THE CELERITY OF RESOLVING LABOUR DISPUTES

Lecturer Ribana CONȚ Ph.D.

"Dimitrie Cantemir" University of Târgu Mureș, Faculty of Law, Romania
Corresponding author: Ribana Conț: ribana.i@gmail.com

Abstract

This paper presents an absolute novelty in post-revolutionary Romanian legislation, according to which any court that resolves labour disputes regarding salary rights of personnel employed in public institutions or social security rights, is obliged, prior resolving the dispute, to request the High Court of Cassation and Justice to resolve the legal issue regarding the underlying dispute. In our opinion, this represents an impermissible interference in the act of justice, likely to affect the independence of the judge and the principle of separation of powers in the state. Another undesirable effect of this regulation is the excessive crowding of the High Court and the excessive prolongation of the litigations targeted by the legislator, in flagrant violation of the principle of speedy judgment of this type of litigation

Keywords: labor disputes, legal issue, independence of the judge, separation of powers.

1. Legal Regulation

The emergence of Government Emergency Ordinance no. 62/2024 regarding certain measures for resolving lawsuits concerning the salaries of personnel paid from public funds, as well as lawsuits concerning social insurance benefits (published in Official Gazette no. 559 of June 14, 2024), was justified by the urgent need to ensure uniform and consistent judicial practice – which would eliminate differentiations in establishing/paying the salary rights of personnel paid from public funds – which benefits both the equal administration of justice and the assurance of equality before the law, as well as socio-economic relations.

In this regard, the government officials noted the existence of a generalized phenomenon with tendencies of permanence in non-uniform judicial practice at the level of courts that resolve lawsuits regarding the establishment and/or payment of salary or salary-related rights of personnel paid from public funds, as well as disputes regarding the establishment and/or payment of pension rights and other social insurance benefits for this personnel, but also the fact that the solutions pronounced in these categories of disputes have a direct and considerable impact on the consolidated general budget, an effect augmented by the need to ensure equality of legal treatment, an imperative confirmed in the practice of the Constitutional Court from the perspective of the principle of equality before the law.

In our opinion, this regulation, although it refers to the same legal mechanism regulated in art. 519 – 521 of the Civil Procedure Code – Notifying the High Court of Cassation and Justice for a preliminary ruling to resolve legal issues, adds to it the mandatory nature of the procedure

in the matters expressly provided for in the ordinance, while simplifying the conditions for notifying the supreme court.

Although the explanatory memorandum of the ordinance considered the current configuration of the preliminary ruling mechanism for resolving legal issues, as well as the binding effect of the ruling issued by the High Court of Cassation and Justice, in full accordance with its constitutional duty to ensure the uniform application and interpretation of the law by all courts in Romania, it was nevertheless considered opportune to adopt an additional legal provision, which however obliges the judge to access this mechanism for unifying judicial practice in the matters mentioned above, considering the need for easy incorporation of the legislative solutions envisaged in the current civil procedure and justice mechanism, showing that this unification of judicial practice would be done without significantly affecting the workload of the supreme court.

According to art. 1 of Government Emergency Ordinance no. 62/2024, its scope is:

- in lawsuits regarding the establishment and/or payment of salary or salary-related rights of personnel paid from public funds,
- in lawsuits regarding the obligation to issue administrative acts or regarding the annulment of administrative acts issued for this personnel,
- in lawsuits regarding the labor and service relations of personnel paid from public funds,
- in lawsuits regarding the establishment and/or payment of pension rights, including those resulting from the updating/recalculation/revision of pension rights and/or those regarding other social insurance benefits of personnel paid from public funds.

Unlike the mechanism regulated by articles 519 – 521 of the Civil Procedure Code, the procedure in question applies regardless of the nature and object of the above lawsuits, the quality of the parties, or the court competent to resolve them.

According to art. 2 para. (1) of the Ordinance, if, during the trial of the cases provided for in art. 1, the judging panel seized with solving the case at first instance or on appeal, verifying and finding that the High Court of Cassation and Justice has not ruled on a legal issue, the clarification of which depends on the merits of the case, and this is not the subject of an ongoing appeal in the interest of the law, it will request the High Court of Cassation and Justice to issue a ruling that will provide a principle resolution to the legal issue with which it was seized.

Also innovative is the fact that the procedure for bringing to the attention of all courts competent to resolve cases with a similar object to the one in which the referral was made is expressly regulated, in order to inform all judges who have cases on their roles in which the legal provision whose resolution is requested is incidental, in order to suspend all cases. In this regard, para. (2) of art. 2 of the Ordinance provides: *Along with the communication to the High Court of Cassation and Justice, a copy of the referral conclusion is sent, by electronic mail, by the referring court to the other courts competent to resolve, at first instance or on appeal, cases of the nature in which it was formulated. The presidents of the competent courts, as soon as they receive a copy of the referral conclusion, take the necessary measures to inform the judges of the corresponding sections of those courts.*

According to para. (3) of the same article, similar cases pending before the courts will be suspended until the preliminary ruling resolving the legal issue is pronounced.

In the event that there are several referrals pending before the High Court of Cassation and Justice, having the same object or whose object is closely related, all these referrals shall be joined (para. 4), with a view to a unitary solution.

2. The Impact of Government Emergency Ordinance No. 62/2024 on the Administration of Justice

Ab initio, we consider that this regulation was not only unnecessary but also infringes upon the principle of judicial independence and adversely affects the expeditiousness of resolving labor disputes.

As previously demonstrated, the procedure for seizing the High Court of Cassation and Justice (HCCJ) to pronounce a preliminary ruling for the resolution of questions of law — regulated by Art. 519–521 of the Civil Procedure Code — already ensured the possibility of unifying judicial practice at the time the afore-mentioned ordinance entered into force. The referral for a preliminary ruling represents a procedure that can be utilized exclusively during the course of a trial in which a question of law is raised or invoked, the resolution of which is decisive for the settlement of that case (I. V. Varga, Considerations regarding the procedure of the preliminary ruling in the context of the new Civil Procedure Code, *Revista Română de Jurisprudență* no. 4/2011, pp. 273-280). It is an instrument with a dual function: on the one hand, it prevents the formulation of appeals in the interest of the law, and on the other hand, its legal effects extend to the solution to be pronounced in the case where the referral was made (M. Nicolae, The appeal in the interest of the law and the preliminary resolution of a new question of law by the High Court of Cassation and Justice in light of the new Civil Procedure Code, *Revista Dreptul* no. 2/2014, pp. 49-73).

In this regard, Art. 519 of the Civil Procedure Code stipulates: If, during the course of a trial, a judicial panel of the High Court of Cassation and Justice, of the Court of Appeal, or of the Tribunal, vested with the resolution of the case in the last instance, finds that a question of law, upon whose clarification the resolution of the merits of the respective case depends, is new and has not been ruled upon by the High Court of Cassation and Justice, nor is it the subject of a pending appeal in the interest of the law, it may request the High Court of Cassation and Justice to pronounce a decision giving a resolution in principle to the question of law with which it has been seized.

Therefore, the object of the referral constitutes a question of law that must meet a series of conditions (enumerated in Art. 519 of the Civil Procedure Code):

- It must be formulated in connection with a pending trial;
- The trial must be pending before the High Court of Cassation and Justice, a Court of Appeal, or a Tribunal;
- The respective court must be vested with resolving the case in the last instance;
- The clarification of the question of law must be decisive for the resolution of the merits of the case in which it was raised;
- It must be new, the High Court of Cassation and Justice must not have ruled upon it, and it must not be the subject of an appeal in the interest of the law.

The novelty introduced by Government Emergency Ordinance No. 62/2024 resides in the mandatory nature of filing the referral to the High Court of Cassation and Justice when the question of law concerns lawsuits regarding salary rights or pension rights of personnel paid from public funds. Regarding the admissibility conditions of the procedure regulated by the Civil Procedure Code, the Ordinance maintains only those referring to the connection of the referred legal issue with the merits of the case, the absence of a prior ruling by the HCCJ on the respective legal issue, and the absence of a pending appeal in the interest of the law regarding the respective question.

It is worth noting that the conditions regarding the novelty of the issue and the procedural stage of the case (last instance) are no longer maintained.

Among all the differences observed compared to the common law procedure, the one that raises serious questions regarding its legitimacy is the mandatory nature of this procedure. Practically, the judge vested with resolving the cases targeted by the ordinance no longer has the right to resolve the incidental questions of law himself/herself, being obliged to seek the "guidance" of the High Court of Cassation and Justice. This situation reduces the role of the judge in other courts to that of a spectator of the law; they can, at most, assess the evidence and the factual situation, while the assessment of incidental questions of law is removed from their competence. We consider that this regulation violates the principle of judicial independence.

In this sense, Art. 2 para. (3) of Law no. 303/2022 on the Status of Judges and Prosecutors provides that judges are independent and subject only to the law. Judges resolve cases based on the law, respecting the procedural rights of the parties, without constraints, influences, pressures, threats, or direct or indirect interventions from any person or authority. Furthermore, para. (4) of the same article provides that any person, organization, authority, or institution is duty-bound to respect the independence of judges.

However, the obligation to request an interpretation of any question of law concerning salary rights or pension rights of personnel paid from public funds represents a direct intervention of the executive power (following the adoption of the ordinance in question) which gravely affects the independence of judges, as they are no longer subject to the law, but to the will of the executive power and the decisions of the supreme court.

Furthermore, the obligation to seize the High Court of Cassation and Justice may stimulate "complacency" and the divestment of responsibility among judges, although the referral should rather represent a means of collaboration between judges, with a view to resolving a difficult question of law and ensuring a unitary interpretation and application of the legal norms in force (M. Nicolae, *op. cit.*, p. 55).

We consider that these legal provisions also violate the principle of the expeditiousness of the civil process (celerity), as reality has proven that a very large number of cases have been suspended pending the judgment of preliminary referrals. Moreover, the supreme court has become overburdened, a fact that has led to the setting of long court dates, delayed reasoning of decisions, and the resumption of suspended cases with gaps that sometimes reach more than a year. Even though the ordinance provides that referrals having the same object or whose objects are closely related shall be joined, that they shall be judged with priority within at most 60 days from the date the HCCJ is seized, and that the decision shall be reasoned within at most 15 days from pronouncement and published within at most 5 days from reasoning in the Official Gazette—measures attempting to accelerate the act of justice—in fact, these deadlines cannot be respected due to the high volume of referrals.

3. Conclusions

We consider that imposing the mandatory referral to the High Court of Cassation and Justice for the resolution of questions of law in the situations and conditions provided by Government Emergency Ordinance No. 62/2024 is of a nature to disrupt the "proper administration of justice and its prestige," argued by the fact that:

- It encourages judges to transmit the responsibility for resolving any question of law that could influence the outcome of the trial, in all cases, to the special panel of the High Court of Cassation and Justice;
- It causes excessive and unjustified congestion of the supreme court with referrals concerning questions of law, under conditions where many of the referred legal issues do not even imply serious difficulties of interpretation;
- It creates an incompatibility with the principle of the indivisibility of the dispute regarding the assessment of elements of law and fact. Thus, the court that has seized the High Court of Cassation and Justice with the resolution of the question of law retains only the prerogative of assessing the de facto situation, to decide if it falls within the legal framework established before the supreme court (I. Deleanu, *Treatise on Civil Procedure*, Universul Juridic Publishing House, Bucharest, 2013, Vol. II, p. 391);
- It infringes upon the principle of the judge's independence.

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APPROACHING MULTI-LEVEL STUDENTS IN ESP

Assist. Professor Anca SLEV Ph.D.

"Dimitrie Cantemir" University of Târgu Mureș, Faculty of Law, Romania
Corresponding author: Anca Slev: ancampl@yahoo.com

Abstract

Teaching English for Specific Purposes (ESP) to multi-level learners remains a significant challenge for educators, particularly in the domain of Legal English, where specialized vocabulary, discourse conventions, and analytical skills intersect with language proficiency. This paper examines effective pedagogical strategies for addressing the diverse linguistic and cognitive needs of students in Legal English courses. It argues that a flexible, learner-centered approach—grounded in principles of differentiated instruction, scaffolding, and task-based learning—can effectively accommodate students' varying levels of competence while maintaining the rigor required by legal discourse. The paper further highlights the importance of authentic legal materials, such as case briefs, contracts, and statutes, which not only contextualize language learning but also promote critical thinking and professional communicative competence. By integrating collaborative activities, formative assessment, and needs analysis, instructors can create an inclusive learning environment that supports progression from general English proficiency to domain-specific expertise. The study concludes that successful ESP instruction in multi-level Legal English settings depends on balancing linguistic accessibility with professional authenticity, fostering learner autonomy, and continuously adapting instructional practices to reflect students' evolving needs. Such an approach not only enhances linguistic performance but also empowers learners to engage confidently in real-world legal communication.

Keywords: English for Specific Purposes (ESP), Legal English, differentiated instruction, task-based learning, scaffolding, learner autonomy

Introduction

English for Specific Purposes (ESP) has become increasingly relevant as globalization drives the need for professionals who can operate effectively in specialized English-mediated environments. Legal English, in particular, is a high-stakes domain requiring precision, analytical clarity, and the ability to understand and produce complex texts. Unlike general English courses, Legal English involves not only linguistic competence but also knowledge of legal reasoning, legal terminology, and discourse structures characteristic of legal practice.

However, Legal English courses are often populated by heterogeneous learners. These may include law students with varying levels of English proficiency, students with strong legal backgrounds but limited language skills, or law students with little legal knowledge but advanced proficiency in English. This diversity creates significant pedagogical challenges. A curriculum designed for advanced learners may overwhelm beginners, while one tailored for

lower-level students may fail to engage more proficient learners. Teachers must therefore navigate linguistic, cognitive, and disciplinary differences simultaneously.

Existing literature in ESP emphasizes the importance of needs analysis [1], learner-centered instruction [2] and task authenticity [3]. Yet, far less research explicitly addresses how these principles apply within multi-level Legal English classrooms. The complexity of legal discourse amplifies the difficulties typically associated with multi-level teaching, especially when the learning objectives involve mastering specialized genres such as case briefs, client interviews, legal memos, rulings, bills or contract clauses.

This paper aims to address this gap by exploring strategies that enable Legal English teachers to support diverse learners while maintaining the intellectual rigor of legal communication. Drawing on classroom observations, learner feedback, and teacher reflections, the study argues that differentiated instruction, scaffolding, and task-based learning form a powerful pedagogical triad. These approaches, when supported by authentic materials and ongoing formative assessment, help create an inclusive environment where students can progress from general English proficiency toward domain-specific expertise.

The remainder of this paper is structured as follows. The methodology section outlines the qualitative approach used to analyse classroom practices. The participants section describes the heterogeneous group that formed the basis for the study. Next, the materials and methods section details the instructional practices implemented over the course. The results section synthesizes findings related to learner engagement, autonomy, collaboration, and communicative competence. The paper concludes with pedagogical implications and recommendations for future research.

A significant body of ESP scholarship underscores that learners' linguistic needs are tightly intertwined with their professional and academic trajectories, making the precision of instructional design especially crucial in high-stakes fields like law [4, 5]. Legal English presents a particularly demanding subdomain of ESP because it requires students to develop proficiency in language that is highly technical, convention-laden, and often conceptually dense. Legal discourse is characterized not only by specialized terminology but also by complex syntactic structures, nominalization, passive constructions, and unique genres such as case briefs, memoranda, judicial opinions, pleadings, and statutory provisions. These features impose cognitive and linguistic demands that intensify when students enter the course with uneven proficiency levels, prior exposure, or disciplinary backgrounds. Consequently, instructors must negotiate the tension between maintaining the authenticity of legal language and ensuring accessibility for students who may still be developing fundamental English skills.

The challenge is further compounded by the heterogeneity of learner profiles typically encountered in Legal English classrooms. Students may differ not only in baseline linguistic competence but also in legal knowledge, academic literacy, critical thinking skills, and familiarity with analytical reasoning. For example, some learners may have strong grammatical foundations but struggle to interpret legal concepts; others may possess domain knowledge but lack the linguistic resources to articulate arguments clearly. These disparities complicate the pacing of instruction and the selection of appropriate materials, often leaving instructors uncertain about how to support weaker learners without slowing down stronger ones. In this context, the adoption of a differentiated and learner-centered pedagogical framework becomes essential. Differentiated instruction —originally conceptualized for heterogeneous mainstream classrooms [6]— has increasingly been recognized as a viable approach in ESP because it encourages flexible grouping, varied task design, and multiple learning pathways that accommodate different levels of readiness.

Moreover, the growing emphasis on communicative competence in legal education further necessitates instructional strategies that simulate authentic professional tasks. Traditional language teaching methods, which rely on decontextualized grammar drills or vocabulary memorization, fall short of preparing learners for the interpretive, argumentative, and collaborative nature of legal communication. Contemporary ESP pedagogy instead highlights the importance of task-based learning [7, 8], wherein learners engage with meaningful tasks that mirror real-world legal activities. In Legal English, such tasks might include drafting simplified case briefs, negotiating contractual terms, preparing oral arguments, or analysing court decisions. When appropriately scaffolded, these tasks allow students at varying proficiency levels to contribute meaningfully while progressing toward more complex communicative behaviour. Scaffolding—grounded in sociocultural theory and the concept of the Zone of Proximal Development—provides structured support that is gradually withdrawn as learners gain autonomy [9, 10]. This study integrates scaffolding as a key mechanism for ensuring that all students, regardless of starting point, can participate in legal discourse practices.

A further motivating factor for this study is the ongoing debate regarding the use of authentic legal materials in ESP courses. While some scholars caution that unmodified legal texts may overwhelm lower-proficiency learners, others argue that authenticity is indispensable for fostering professional literacy and preparing students for real-world communication [11]. This research aligns with the latter perspective while acknowledging the need for carefully staged instructional sequencing. By gradually introducing authentic materials, from simplified statutes to excerpts of case law, the course design aims to preserve the integrity of legal discourse while preventing cognitive overload. The combination of authenticity and accessibility is central to the pedagogical model examined in this study.

Despite the theoretical advances in ESP, empirical research specifically addressing multi-level Legal English classrooms remains limited. Most studies focus on general ESP contexts or assume relatively homogeneous groups, leaving a gap in the literature regarding how mixed-ability learners navigate specialized legal content. Furthermore, existing research rarely examines the interplay between differentiated instruction, scaffolding, and task-based learning within a unified course design. The present study addresses this gap by evaluating a pedagogical model implemented in a heterogeneous group of Legal English learners. Through qualitative classroom data, the study analyses how students at varying proficiency levels respond to instructional adaptations, engage with authentic legal materials, and progress in their discourse competence.

Preliminary observations indicate that multi-level learners benefit from structured opportunities for collaboration, particularly when tasks are designed to allow for role differentiation. Pair and group work enable stronger learners to articulate reasoning processes while supporting peers, fostering mutual scaffolding among students. Additionally, formative assessment emerged as a key driver of learner progress, as ongoing feedback allowed instructors to identify emerging needs, adjust instructional pacing, and tailor materials more precisely. These findings highlight the dynamic nature of ESP instruction in multi-level settings, where continuous adaptation is essential for sustaining learner engagement and ensuring equitable learning outcomes.

Ultimately, the introduction of a flexible, learner-centered instructional model appears to offer help in pedagogical challenges in Legal English. By acknowledging and leveraging learner diversity rather than treating it as a barrier, language teachers can cultivate an inclusive environment that promotes linguistic development, critical thinking, and proficiency. The

present study contributes to the broader field of ESP by demonstrating that multi-level instruction- when grounded in research-based pedagogical principles - can support meaningful engagement with complex professional discourse. The subsequent sections of this paper outline the research methodology, materials and methods, empirical results, and implications for Legal English pedagogy.

Research Methodology

This study employed a qualitative descriptive methodology aimed at generating insights into effective pedagogical practices within multi-level Legal English classrooms. Qualitative methods were chosen because the research questions focus on instructional processes, learner experiences, and classroom dynamics rather than quantifiable linguistic outcomes.

Three primary data sources were used: classroom observations, teacher reflections and notes, and student feedback.

Over a 14-week semester, observations were conducted during a Legal English introductory course taught in English. Observation notes focused on learner behaviours, types of interaction, response to instructional materials, and challenges encountered during tasks. Particular attention was given to how learners of different proficiency levels engaged with the same activities.

The teacher kept weekly reflective journals documenting the rationale behind pedagogical choices, assessments of classroom atmosphere, and perceptions of student progress. These reflections provided insight into which instructional strategies were most effective, and which required modification.

Semi-structured interviews and end-of-semester evaluations were collected from students. Interview questions focused on perceived difficulty levels, usefulness of materials, satisfaction with collaborative tasks, and perceived improvements in legal English skills. This feedback helped triangulate findings from observations and teacher reflections.

Data were analysed using thematic analysis. Observation notes, reflections, and feedback were used to identify recurring themes related to engagement, comprehension, autonomy, and perceptions of authenticity. These themes were then grouped into broader categories that aligned with the instructional frameworks of differentiated instruction, scaffolding, and task-based learning.

This methodology allowed for the construction of a comprehensive narrative about how teaching strategies functioned in real classroom contexts and how learners across proficiency levels responded to instructional challenges.

Participants

The study involved 30 students enrolled at the Faculty of Law, at Dimitrie Cantemir University of Târgu Mureş. These participants study Legal English for a period of 4 semesters (14 weeks each), during their first and second year of study, but the study was conducted during the second semester of the first year of study. The students use Romanian as the primary medium of instruction for law-related subjects, while English serves as the medium of instruction for the Legal English classes only. The participants varied significantly in age, language proficiency, academic background, and previous exposure to legal materials.

After working with the participants for a semester, three main learner profiles were identified: Beginner to Lower-Intermediate (A2–B1) (n = 7), Intermediate to Upper-Intermediate (B1+–B2) (n = 15), and Advanced (C1) (n = 8).

The first group of learners possessed limited vocabulary, struggled with complex sentence structures, and had diverse prior knowledge of legal terminology. They often required additional scaffolding to comprehend even simplified legal texts.

The second group of students displayed moderate communicative competence, and some showed familiarity with legal concepts, while others had no prior knowledge of the field. They were generally able to understand simplified legal texts but required support when engaging with authentic materials.

The third group included students with strong academic backgrounds in law or law enforcement. They sought advanced communicative skills, especially in drafting, argumentation, and oral legal communication.

The identification of these learner profiles had important classroom implications. The range of proficiency levels meant that a single-level curriculum would inevitably disadvantage some learners. The necessity for differentiated instruction became immediately apparent, as did the importance of strategically grouping students to leverage peer learning. The diversity of participants provided a natural laboratory for examining multi-level instructional strategies in ESP.

Materials and Methods

The course *materials* were selected to promote both accessibility and authenticity [4, 11]. To support multi-level learners, each genre or legal topic was presented using instructional materials of varying complexity. Because Legal English learners must eventually operate within real legal discourse, authentic texts were incorporated to expose students to genuine genre conventions and professional terminology. This approach aligns with Hutchinson and Waters' view that ESP materials should reflect the communicative realities of the target domain [12].

To meet the needs of multi-level learners, materials were adapted using scaffolding techniques recommended by Nation [13] and Richards and Rodgers [14]. These adaptations included simplified versions of judicial opinions, annotated statutory paragraphs, and glossaries that supported comprehension while maintaining the integrity of the original legal content. Multimedia resources such as courtroom recordings and lawyer–client interviews were included to develop pragmatic competence, responding to Hyland's argument that disciplinary literacy encompasses both linguistic and socio-pragmatic dimensions [5].

The types of materials used also included Case briefs (Both full-length judicial opinions and simplified summaries were used. Beginners focused on identifying parties, facts, and outcomes; advanced students analysed issues, reasoning, and dissenting opinions.), Contracts and legal clauses (Students examined employment contracts, confidentiality agreements, and service contracts. Beginners worked with highlighted clauses and glossaries; advanced learners rewrote ambiguous clauses and negotiated revisions.), Statutory texts (Excerpts from penal codes, civil codes, and administrative regulations were used to teach statutory interpretation. Vocabulary annotations supported lower-level learners.) Audio and video materials were used to develop listening comprehension and pragmatic competence: courtroom exchanges, lawyer–client consultations, and legal practitioner interviews.

In addition to these, teacher-created scaffolding tools were employed. These included vocabulary lists, graphic organizers, case brief templates, sentence stems, flow charts, and

simplified text versions were developed in accordance with Tomlinson's recommendations for materials that promote learner engagement and cognitive support [15]. These tools increased accessibility without diminishing the authenticity of the legal texts.

The combination of authentic and scaffolded materials ensured that all learners engaged with meaningful content while still receiving needed linguistic support.

The main teaching **methods** used were differentiated instruction (DI), scaffolding, task-based learning (TBL).

Differentiated instruction was implemented both in content and in activity design to accommodate learners' diverse linguistic backgrounds and legal knowledge. This approach is grounded in the pedagogical claims of Tomlinson [16], who emphasizes modifying content, process, and products to meet learners' readiness levels. Tasks were structured so that all students worked on the same topic or text but at different depths. Examples include tiered reading tasks for case briefs, chunked writing tasks where advanced learners drafted full paragraphs while beginners completed sentence frames, choice-based assignments allowing students to select between levels of difficulty. Differentiation prevented advanced learners from feeling unchallenged while protecting lower-proficiency learners from cognitive overload. This model supports the ESP principle that learner needs, not textbook progression, should guide instruction [12].

Scaffolding strategies (based on Vygotskian sociocultural theory as applied to language learning [10] and Gibbons' work on scaffolding in linguistically diverse classrooms) were essential to ensuring comprehension, particularly during engagement with authentic materials. The key scaffolding techniques included pre-teaching legal vocabulary and concepts before reading, using guiding questions to support text analysis, providing sentence frames for oral and written legal argumentation, modelling legal genre structures. Gradually support was reduced or adjusted based on formative assessment results, as learners gained confidence and proficiency, aligning with Wood, Bruner, and Ross's original formulation of scaffolding as support that fades over time [17].

Task-Based Learning (TBL) formed the communicative backbone of the course. The tasks were designed to mirror real-world legal communication and promote authentic language use. Activities such as client interviews, contract negotiations, and case presentations engaged learners in meaningful interaction while encouraging them to apply legal terminology and reasoning. As Long argues, pedagogical tasks that replicate real-world conditions are particularly effective in professional ESP contexts [8].

Each task was sequenced from structured to open-ended forms, supporting learners' developing competence. Task repetition and post-task reflection further strengthened fluency, accuracy, and complexity.

Results

Preliminary analysis of the study's classroom observations, learner feedback, and teacher reflections reveals several key outcomes that shaped the interpretation of the teaching strategies examined. The results indicate that the combined use of differentiated instruction, scaffolding, and task-based learning significantly enhanced learners' engagement with legal materials, regardless of their initial proficiency levels. Students demonstrated noticeable improvements in their comprehension of legal texts, confidence in participating in legal simulations, and ability to collaborate effectively in mixed-ability groups. Furthermore, the incorporation of authentic legal documents heightened learners' motivation and helped them recognize the relevance of

Legal English to real-world professional contexts. These outcomes collectively suggest that a flexible, learner-cantered instructional approach is particularly effective in supporting diverse learners in Legal English classrooms.

Observation data indicated enhanced comprehension, especially among lower-level learners. Vocabulary pre-teaching and guided reading activities reduced cognitive overload. Students who initially expressed anxiety about legal materials reported greater confidence by mid-semester. Beginners demonstrated measurable improvements in identifying legal issues and summarizing facts, while advanced learners engaged with more nuanced reasoning.

By the second half of the course, many learners — regardless of initial level — began working more independently. Beginners used strategies such as identifying root words, using context clues, and consulting bilingual legal dictionaries. Advanced learners sought supplementary cases and statutes, demonstrating intrinsic motivation. Students also reported feeling more prepared to participate in class discussions, presentations, and legal simulations.

Mixed-level group work fostered reciprocal learning. Advanced learners acted as informal mentors, explaining legal terminology or clarifying concepts for beginners. This process deepened advanced learners' understanding while providing accessible peer explanations for lower-level classmates. Interview data revealed that many students perceived peer learning as one of the most valuable components of the course.

Despite initial difficulty, students consistently expressed appreciation for authentic legal texts. They valued the real-world relevance and believed the materials prepared them for future academic or professional work. Authentic materials also sparked deeper engagement; learners frequently asked follow-up questions about legal concepts, court structures, or professional practices.

Task-based activities resulted in noticeable improvements in oral fluency, legal vocabulary usage, and confidence. Negotiation simulations, client interviews, and mini moot courts were the most highly rated activities. Observation notes indicated increased learner participation during these tasks, as well as more accurate and contextually appropriate use of legal English expressions.

Conclusion

Teaching Legal English in multi-level classrooms requires pedagogical ingenuity and adaptability. This study demonstrates that a combination of differentiated instruction, scaffolding, and task-based learning can effectively support diverse learners while maintaining the intellectual rigor characteristic of legal discourse. Authentic materials enhance relevance and help learners contextualize language use within professional settings, while collaborative tasks foster peer learning and strengthen communicative competence.

The findings suggest several pedagogical implications. First, instructors must continuously assess learner needs and adjust scaffolding levels accordingly. Second, authenticity should not be sacrificed for simplicity; instead, authenticity should be made accessible through guided support. Third, collaborative learning structures should be intentionally embedded within course design. Finally, learner autonomy should be cultivated gradually, enabling students to take increasing responsibility for their learning.

Future research might explore the long-term effects of these instructional strategies on professional performance or examine how technology-enhanced learning tools can further support multi-level Legal English classrooms. Overall, the study highlights that balanced,

flexible, and learner-centered instruction empowers students to develop the linguistic and analytical competencies necessary for success in legal communication.

In addition to highlighting the pedagogical value of differentiated instruction, scaffolding, and task-based learning, the findings of this study emphasize the broader role of adaptability in ESP course design. Legal English teachers must be prepared to respond to fluctuations in learner performance, evolving curricular requirements, and the complexities of legal discourse itself. This study suggests that when teachers consistently monitor learners' development and modify instruction accordingly, multi-level classes can become an opportunity to cultivate engagement, collaboration, and deeper disciplinary understanding. Such adaptability requires institutional support - including professional development, curricular flexibility, and access to appropriate material. This points out that successful multi-level ESP instruction is both a pedagogical and organizational effort.

The findings also point to several promising directions for future research. Longitudinal studies could investigate how multi-level learners progress over extended periods of exposure to Legal English, particularly in relation to their evolving professional identities and communicative confidence. Additional comparative research could also explore how similar learner-centered frameworks function across different branches of ESP, such as Business English or Medical English, to determine which instructional principles hold universally and which require domain-specific modification. Expanding the evidence base in this way would not only refine the theoretical understanding of ESP pedagogy but also equip teachers with more precise tools for managing heterogeneous classrooms.

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THE LEGAL ORDER OF OUTER SPACE IN THE ERA OF MULTIPOLARITY: ARTEMIS VS. THE INTERNATIONAL LUNAR RESEARCH STATION

Assist. Professor Andrei-Bogdan MURGU Ph.D.

"Dimitrie Cantemir" University of Târgu Mureș, Faculty of Law, Romania
Corresponding author: Murgu Andrei-Bogdan: abmurgu95@gmail.com

Abstract

The paper examines the evolution of the normative architecture governing human activities in outer space, focusing on how geopolitical and technological competition is reshaping the rules of space law. From a historical perspective, the study traces the gradual development of major international treaties, from the 1967 Outer Space Treaty to emerging 21st century legal instruments, highlighting the persistent tensions between a cooperative vision of space regulation and the dynamics of great-power rivalries.

The comparative analysis between the Artemis Accords, promoted by the United States and a broad coalition of democratic states, and the International Lunar Research Station (ILRS), a China and Russia led initiative, illustrates how the space law is entering a new phase of normative fragmentation and competition. The Artemis Accords propose a flexible interpretation of the existing legal regime, emphasizing transparency, interoperability, and the possibility for private actors to utilize space resources. In contrast, the ILRS framework reflects the aspiration for an alternative model of space governance, more centralized, orientated toward strategic cooperation within a distinct geopolitical bloc, and implicitly challenging the normative hegemony of the United States.

The paper thus explores whether the emergence of those two parallel regimes anticipates a legal multipolarity in space or, on the contrary, reinstates a form of bipolarity similar to that of the cold war, but expressed through more sophisticated legal structures. The conclusions highlight that outer space is becoming a critical arena for defining the new international order where competition over standards, norms and legal interpretations is as decisive as technological competition.

Keywords: space law, Artemis Accords, ILRS, multipolarity, space resource utilization.

Introduction

With the end of World War II, the great powers of the time, the United States of America (hereinafter, the USA) and the Union of Soviet Socialist Republics (hereinafter, the USSR) entered the well-known Cold War. The ballistic missiles used by Nazi Germany during World War II, the V-2, showed humanity the ability to overcome the limits of the atmosphere and transform space into a potential battlefield. After the end of World War II, this technology was taken over and developed by the great powers of the time, especially the USA and the USSR. As the years passed, the increasingly accelerated development of missiles, and the emergence

of intercontinental missiles, pressured the great powers to consider outer space as a strategic defence domain.

American and international society was completely shaken in 1957 when the USSR successfully launched the first artificial satellite in history, Sputnik 1. American citizens were terrified by the idea that the "Russians" were above their cities and that they would be able to deliver missiles and especially nuclear warheads there. During this period, the USA and the USSR were testing intercontinental ballistic missiles and even space-launched nuclear warheads. At the same time, small and medium-sized villages feared that the Great Powers would divide up space and wanted equal access and common legal status.

Taking into account this global context and the fact that outer space was in an absolute legal vacuum, meaning that international law did not regulate outer space at all, the General Assembly of the United Nations (hereinafter, UN) acted by establishing the UN Committee on the Peaceful Uses of Outer Space (abbreviated, COPUOS), in 1959 [1]. It can be concluded that COPUOS was created as the UN's institutional response to the emergence of a new unregulated strategic area, with major potential for conflict, in a bipolar context, in order to prevent the rapprochement, militarization and fragmentation of outer space. The USA and the USSR agreed to be part of COPUOS and to sit at the negotiating table, not out of legal idealism, but out of fear that the direct rival could gain a temporary technological advantage and could completely dominate outer space or, even worse, appropriate its sovereignty [2]. Thus, COPUOS represented a geopolitical compromise: accepting general principles and limiting sovereignty in space in exchange for maintaining strategic stability and preventing military escalation. Within COPUOS, the great powers, especially the USA and the USSR, negotiated the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies in 1967 [3].

Simply called the "Treaty on Outer Space" (hereinafter "Treaty"), it does not seek to regulate all aspects of the use of outer space, but establishes fundamental principles of general applicability, deliberately leaving economic and commercial matters, including the exploitation of natural resources, outside its scope of regulation. Article I of the Treaty establishes that: "Outer space, including the Moon and other celestial bodies, is free for exploration and use by all States, without discrimination of any kind, on the basis of equality and in accordance with international law". From this article, it can be concluded that the principle of free and equal access to outer space is applied, considering the desire of smaller States to avoid the monopolization of outer space by other, much more powerful actors.

Art. II of the Treaty establishes that "Outer space, including the Moon and other celestial bodies, shall not be the subject of national appropriation by claim of sovereignty, by use or occupation, or by any other means." This prohibition is intended to eliminate the possibility of territorial claims and reduce the risk of conflicts like those historically generated by competition for territory on Earth. It is very important to understand that the wording of Art. II refers exclusively to territorial appropriation and does not contain any explicit mention of the legal status of the natural resources of celestial bodies. This omission will have significant consequences in the subsequent evolution of outer space law.

Another defining article of the Treaty is Article IV, which establishes that the States Parties undertake "not to place in orbit around the Earth any object carrying nuclear weapons or any other weapons of mass destruction, not to install such weapons on celestial bodies or to place them in outer space in any other way". As for the Moon and other celestial bodies, the Treaty establishes that they must be used "exclusively for peaceful purposes", being prohibited "the establishment of military bases, installations and fortifications, the testing of any type of

weapons and the conduct of military maneuvers”. However, the Treaty allows the use of military personnel for scientific or peaceful purposes, confirming that the notion of “peaceful [4]” does not equate to the complete demilitarization of space. Article VI specifies that the main subject of law within outer space is the State, regardless of the possibility of the appearance of private actors, placing the entire responsibility on States. Specifically, “the States Parties to the Treaty bear international responsibility for national activities in outer space, including on the Moon and other celestial bodies, regardless of whether these activities are carried out by governmental bodies or non-governmental entities” (Article VI, Sentence I).

To continue the legal analysis and the conclusion of the study, it is essential to understand that, within the Outer Space Treaty, there is no regulation on the exploitation of the natural resources of the Moon or other celestial bodies [5]. The Treaty does not contain provisions on the ownership of extracted resources, the conditions of their exploitation or the distribution of the resulting benefits. This normative silence is not an accidental gap, but the result of a political compromise necessary for the adoption of the Treaty in a bipolar context. In 1967, the inclusion of economic rules or an international resource regime would have compromised the consensus between the great powers and prevented the adoption of the Treaty. Through its general principles and deliberate omissions, the Outer Space Treaty managed to create a common normative framework, flexible enough to be accepted by all the great powers but insufficiently detailed to respond to the challenges generated by subsequent technological and economic developments. This structure explains both the longevity of the Treaty and the emergence of divergent interpretations in the current multipolar context [6]. The treaties concluded after the 1967 Outer Space Treaty, namely the Astronaut Rescue Agreement (1968) [7], the Convention on International Liability for Damage Caused by Space Objects (1972) [8] and the Convention on Registration of Objects Launched into Outer Space (1975) [9], attempted to consolidate a technical and procedural framework for space activities. These instruments addressed humanitarian cooperation, attribution of responsibility and transparency, but did not address the issue of exploitation of the natural resources of celestial bodies. Although these treaties remain relevant for issues such as State responsibility and risk management associated with space activities, they do not provide answers to the fundamental questions regarding the economic use of outer space, which constitute the main stakes of contemporary debates.

With the passage of time and technological advancement, the USA successfully completed the Apollo Program and successfully landed on the Moon [10] on July 20, 1969 [11]. As a result of these events, COPUOS took the initiative and brought the most important actors to the negotiating table to negotiate the “Agreement Governing the Activities of States on the Moon and Other Celestial Bodies [12]”, marginally called the “Moon Agreement.” Unlike the Outer Space Treaty, the Moon Agreement aimed to clarify certain aspects and create a clear regulatory framework, as well as to regulate, among other things, the exploitation of natural resources of other celestial bodies.

Under the Moon Agreement, art. 4, it states: “1. The exploration and use of the Moon shall be the prerogative of all mankind and shall be carried out for the benefit and in the interest of all countries, regardless of their degree of economic or scientific development. Due regard shall be paid to the interests of present and future generations, as well as to the need to promote higher standards of living and conditions of economic and social progress and development, in accordance with the Charter of the United Nations; 2. States Parties shall be guided by the principle of cooperation and mutual assistance in all their activities relating to the exploration and use of the Moon. International cooperation under this Agreement shall be as broad as possible and may take place on a multilateral basis, on a bilateral basis or through international

intergovernmental organizations.” This article maintains the cooperation provided for in the Outer Space Treaty of 1967. Also under the Moon Agreement, art. 6 states: “1. All States Parties shall have the freedom to conduct scientific investigations on the Moon, without any discrimination, on a basis of equality and in accordance with international law; 2. In carrying out scientific investigations and for the purpose of implementing the provisions of this Agreement, States Parties shall have the right to collect and take from the Moon samples of minerals and other substances thereof. Such samples shall remain at the disposal of States Parties which have requested their collection and may be used by them for scientific purposes. States Parties shall consider the desirability of making a portion of such samples available to other interested States Parties and to the international scientific community for scientific investigations. States Parties may also use during scientific investigations minerals and other substances of the Moon in quantities adequate to support their missions; 3. States Parties agree on the desirability of exchanging scientific and other personnel on lunar expeditions or installations to the greatest extent possible and practicable.” Here we note that, unlike the 1967 Treaty, the Moon Agreement considers the taking of samples, so it is implicitly a legal evolution, which comes concurrently with the technological evolution that has taken place in these years.

The most important provision for the topic we are analyzing within the Moon Agreement is art. 11, which seeks to regulate certain aspects that the 1967 Outer Space Treaty completely avoided regulating. Specifically, para. 1 of art. 11 provides that “The Moon and its natural resources constitute the common heritage of mankind”, and para. (2) states that “The Moon shall not be subject to national appropriation by any claim to sovereignty, by use or occupation or by any other means”. Finally, para. (3) provides that “neither the surface nor the subsoil of the Moon, nor any part thereof, nor the natural resources on the site shall become the property of any State, international intergovernmental or non-governmental organization, national organization or non-governmental entity, or any natural person”. From all that has been presented, we can conclude that the Agreement intended to extend the principle of non-approach, from territory to resources. The Moon Agreement aimed to create a much clearer regulatory framework, strengthen the principles set out in the 1967 Treaty and attempted to regulate the use of resources on other celestial bodies.

The Moon Agreement was adopted by the UN in 1979 and formally entered into force in 1984. However, it is considered a failure. [13] The problem was that it was ratified only by small states without real space capabilities. In contrast, large states such as the USA, the USSR and the People's Republic of China refused to ratify the Agreement.

After the failure of the Moon Agreement, space law remained in a legal vacuum regarding resource exploitation, although technology began to advance at an increasingly accelerated speed. If during the Cold War, we could only talk about two main actors, namely the USA and the USSR, with the passage of time, numerous new actors have appeared on the space scene. For example, we list: National Aeronautics and Space Administration (NASA), the US space agency; China National Space Administration (CNSA), the Chinese space agency; Roscosmos, the Russian space agency; European Space Agency (ESA), the European Union space agency; Indian Space Research Organisation (ISRO), the Indian space agency; Japan Aerospace Exploration Agency (JAXA), the Japanese space agency [14]. In modern times, we can even talk about private space actors, for example, SpaceX or Blue Origin [15]. It is important to mention this aspect in order to understand that we are in an area of multipolarity, with more and more actors competing with each other.

Things changed in 2017 when NASA launched the Artemis program, with the clear mission of returning to the Moon, moreover, they also aimed to bring sustainable human and robotic presence to the Moon, not just isolated missions. In 2020, the USA initiated and promoted the Artemis Accords through NASA [16]. The Artemis Accords are a set of multilateral political agreements, through which the signatory states assume a common interpretation of how existing outer space law applies. There were 8 initial signatories, namely: Australia, Canada, Italy, Japan, Luxembourg, the United Arab Emirates, the United Kingdom and the United States. To date, there are 60 signatories, including Romania [17]. In response, China, which already had a lunar program called “Chang’e” together with Russia, signed a memorandum on the construction of the International Lunar Research Station (ILRS) [18]). Subsequently, China and Russia invited other states to join through bilateral memoranda and cooperation agreements with their space agencies (CNSA and Roscosmos, respectively). In practice, ILRS focuses more on projects than on norms. It is essential to clarify that neither the Artemis Accords nor the ILRS project were developed under the auspices of the UN. Both initiatives operate outside the established multilateral framework, promoting distinct interpretations of existing space treaties, in the absence of a universal normative coordination mechanism.

Returning to the subject of the study and approaching its conclusion, Section 10 of the Artemis Agreements, entitled “Space Resources”, states the following: “1. The Signatories note that the use of space resources can bring benefits to humanity by providing essential support for safe and sustainable operations; 2. The Signatories emphasize that the extraction and use of space resources, including any recovery from the surface or subsoil of the Moon, Mars, comets or asteroids, shall be carried out in a manner consistent with the Outer Space Treaty and in support of safe and sustainable space activities; 3. The Signatories affirm that the extraction of space resources does not, in itself, constitute a national appropriation within the meaning of Article II of the Outer Space Treaty and that contracts and other legal instruments relating to space resources shall be consistent with that Treaty; 4. The Signatories undertake to inform the Secretary-General of the United Nations, as well as the public and the international scientific community, with regard to their space resource extraction activities, in accordance with the Outer Space Treaty. The Signatories intend to use the experience gained under the Agreements to contribute to multilateral efforts to further develop international practices and norms applicable to the extraction and use of space resources, including through ongoing efforts within COPUOS.”

As can be seen, there is open talk about resource exploitation, that is, exactly the criterion regulated by the Moon Treaty. We must also take into account the fact that the ILRS has as its objective the construction of a permanent base on the moon, and the signing of the memorandum was done in compliance with international law. If the Moon Treaty has not been ratified, it leaves open the possibility that the ILRS project will also take into account the extraction of resources. What we are trying to highlight is the fact that we have 2 blocks, which interpret Space Law in their own style, and which are moving towards a common goal.

Conclusions

The analysis of the evolution of the legal order of outer space highlights the fact that international space law was initially conceived as an instrument for preventing conflicts in a bipolar system, in which normative ambiguity allowed for the maintenance of stability. The 1967 Outer Space Treaty succeeded in fulfilling this role, but it was not designed to regulate

the economic use of outer space in a multipolar context characterized by accelerated technological progress.

The failure of the 1979 Moon Agreement to obtain ratification by the major powers left the issue of space resource exploitation unresolved, generating a legal vacuum that has become increasingly evident with the resumption of lunar ambitions. The emergence of the Artemis Accords and the ILRS project illustrates this situation, two major initiatives, developed outside the UN framework, which claim the same fundamental principles, but interpret them differently, without a common legal coordination mechanism. This normative fragmentation does not necessarily imply imminent conflict, but creates the premises for legal and political tensions, especially in the context of the use of space resources and the establishment of *de facto* practices.

In the absence of common rules, the risk lies not so much in the immediate militarization of outer space, but in its transformation into a field of unregulated competition, in which the law reacts *post-factum*. In this context, the need for international regulation becomes evident. It is not necessarily about adopting a new exhaustive treaty, but about reconstructing a common legal space, capable of ensuring compatibility of interpretations and maintaining outer space as a field of cooperation.

Technological progress amplifies the power of action of states, and, correspondingly, imposes increased legal responsibility. Without this shared responsibility assumed, the risk of terrestrial rivalries being projected into outer space remains open.

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DIGITALIZATION AND USE OF ARTIFICIAL INTELLIGENCE IN THE NOTARIAL FIELD

PhD univ. assist. Raluca-Ioana HURUBĂ

“Dimitrie Cantemir” University of Tg. Mureș, Faculty of Law, Romania
Corresponding author - Raluca Huruba: raluca_huruba@yahoo.com

Abstract

Digitalization in the notarial field must be done in a planned manner, with careful weighing of all risks, so that electronic notarial activity maintains or even increases the level of trust and security that notaries currently enjoy and, at the same time, fully reaps the benefits of digitalization. From this point of view, it is possible that notaries' concern about notarial activities not being affected, in terms of trust and security, may be misinterpreted as their opposition or fear of the digitalization trend.

In recent decades, society has entered an era of accelerated digital transformation, in which technology is redefining the way legal institutions and professions operate. The notarial profession, characterized by traditionalism and rigor, is faced with the need to adapt to new technological tools, which can contribute to increasing the efficiency, transparency and accessibility of legal services.

Digitization and artificial intelligence (AI) are two essential factors in this evolution, offering significant opportunities for modernization, but also challenges regarding the regulation, ethics and security of legal information.

The article analyzes the impact of the digitalization process and artificial intelligence (AI) on the notarial profession, from the perspective of the modernization of legal activity and the ethical and legislative challenges generated by these transformations. It highlights the advantages of digitalization in increasing the efficiency and transparency of the notarial act, the emerging role of AI in automating processes and document analysis, as well as the need to adapt the legal framework to new technological realities. The study concludes that the notary of the future will combine traditional legal skills with digital skills, maintaining the fundamental principles of legality and public trust.

Keywords: digitization, artificial intelligence, notarial activity, digital transformation, law and technology.

1. Introduction

Digital transformation represents one of the most significant developments of the early 21st century in the legal field. Notarial activity, traditionally entered on physical documents and the physical presence of the parties, is on the verge of a profound change through the implementation of digital solutions and artificial intelligence technologies (hereinafter referred to as AI). The digitalization of notarial activity aims to increase efficiency, access to information, procedural transparency, and legal certainty, adapting the profession to the new requirements of the information society and the European Union. However, this process is not

without challenges, including ethical concerns, data protection issues, and the liability of the public notary.

Digitalization and artificial intelligence (AI) represent two major directions of contemporary legal transformation, significantly influencing the notarial profession. While digitalization has enabled the transition to electronic documents, digital authentication systems, and online procedures, AI introduces an additional level of automation, data analysis, and decision support.

This article examines the evolution of digitalization in notarial activity, the gradual integration of AI into notarial practice, the legal and ethical implications of these transformations, and the manner in which European states — including Romania — are adjusting their legislative frameworks to respond to these new realities. The paper highlights both the transformative potential of emerging technologies and the clear limitations arising from the specific role of the notary as a public authority.

2. Digitalization and Artificial Intelligence in the Legal Field

Digitalization in the legal field refers to the transformation of traditional processes into electronic processes through the use of information technologies for the generation, archiving, transmission, and consultation of legal documents. In this context, artificial intelligence represents a set of technologies capable of performing tasks that previously required human intervention, through machine learning algorithms and natural language processing [1].

In notarial activity, the integration of AI offers the potential to automate repetitive or complex tasks, such as verifying the compliance of contractual clauses, assessing risks, or consulting databases, thereby reducing processing time and minimizing human error [2].

At present, under the influence of digitalization and the accelerated development of technologies such as artificial intelligence and cybersecurity, a new stage in the evolution of law is taking shape. In this context, it is necessary to analyze two essential directions: on the one hand, how these transformations affect the substance of legal norms themselves, and on the other hand, their impact on the exercise of legal professions.

It is evident that new technologies directly influence the manner in which legal professions are practiced. In recent years, the automation of certain legal processes through artificial intelligence has become an undeniable reality, raising legitimate questions regarding the future of these professions and how legal professionals should relate to these transformations.

Although, at first glance, this evolution might be perceived as a threat - namely, the diminishing role of the human factor in the administration of justice - it is important to emphasize that, at the current stage of development, emerging technologies do not replace legal professionals but rather lead to a redefinition of their roles. In this context, adaptability and continuous professional training become essential. Legal professionals will need to acquire new skills that allow them to collaborate effectively with artificial intelligence and to better understand its impact on law and jurisprudence.

3. Legal Framework and European Regulations

At the European level, the European Union has adopted an extensive regulatory framework regarding the digitalization of services and the use of emerging technologies. Regulation (EU) 2016/679 on data protection (GDPR) governs the processing of personal data, including within the digital notarial environment, imposing strict requirements concerning confidentiality and information security.

More recently, the Artificial Intelligence Act, adopted in 2024 by the European Parliament and the Council of the European Union, provides a regulatory framework for the use of AI in sensitive sectors, including the legal field, imposing requirements related to transparency, accountability, and the risks associated with intelligent systems.

The digitalization of the European notarial system has been stimulated by the adoption of the eIDAS Regulation, which created a unified framework for electronic identification, electronic signatures, and trust services. eIDAS allows Member States to develop digital notarial procedures without compromising the authentication of documents [3].

4. Artificial Intelligence – Role and Benefits in Notarial Activity

Artificial intelligence can significantly transform the way notarial activity is carried out. Among the main benefits are:

- the automation of document drafting and the generation of standardized texts, reducing working time and the risk of human error;
- data analysis and verification of document compliance with current legal norms, through algorithms capable of interpreting complex clauses;
- optimization of search systems within electronic records for the rapid identification of authentic information.

For example, an AI system integrated into an electronic notarial platform could suggest standard additions or amendments for certain legal acts or could verify a document to prevent inconsistencies with current legislation, thus facilitating the work of the public notary [1].

5. Ethical and Regulatory Challenges of AI in Notarial Activity

Although the advantages of AI are evident, its adoption in notarial activity raises normative and ethical challenges. The primary concern relates to legal certainty and the professional liability of the public notary. AI algorithms may commit errors or propose automated legal interpretations that do not reflect the nuances of a specific case, raising questions regarding the liability of the public notary for the documents drawn up.

A second aspect concerns the ethics of personal data use. The use of AI involves the processing of large volumes of sensitive data belonging to the parties involved in notarial acts, requiring strict compliance with GDPR and best practices in information security.

Moreover, in the context of AI, concepts such as the transparency of automated decisions and the explainability of those decisions become critical; algorithmic decisions must be capable of being explained and justified from a legal perspective in order not to undermine the fundamental principles of law and notarial procedure.

A key aspect is that the public notary cannot invoke AI to excuse potential errors, as liability for the documents drawn up remains exclusively with the notary. AI may generate draft documents, but it is the notary who verifies the identity of the parties, the compliance of the acts, and their legal effects. Thus, AI functions as a support tool, similar to legal databases or computer-assisted translation tools.

6. Digitalization in Notarial Activity

An essential element of the digitalization of notarial activity in Romania is represented by the national electronic notarial registers administered by the National Center for the

Administration of National Notarial Registers (CNARNN) – Infonot. CNARNN is the structure established by the National Union of Public Notaries of Romania to organize and manage national notarial registers in accordance with the provisions of the Law on Public Notaries and the implementing regulations (Law no. 36/1995; CNARNN Organization and Functioning Regulation, 2014), providing the technical infrastructure necessary for centralized national records.

The National Notarial Register of Successions (RNNES), the National Notarial Register of Liberalities (RNNEL), the National Notarial Register of Successional Options (RNNEOS), and other similar registers are maintained in electronic format at the national level and allow the registration, updating, and consultation of data by public notaries and other authorized institutions under the law.

These electronic registers centralize relevant information on notarial acts, such as donations, testamentary dispositions, powers of attorney, and matrimonial regimes, enabling the rapid and secure verification of legal situations in an interoperable manner among notarial offices throughout the country.

Access to the national electronic notarial registers is provided through secure IT applications available to all active public notaries and may also support integration with other electronic systems of public administration.

Another concrete example of digital infrastructure used in Romanian notarial practice is the iNot application, developed within CNARNN/Infonot and made available to public notaries. This platform offers modules for managing notarial office activities, including the creation, storage, and electronic transmission of documents, as well as interconnection with central records.

The implementation of such solutions contributes to increased internal efficiency and system interoperability and reflects the way digitalization is transforming traditional practices within a conservative legal profession.

7. Replacement of Legal Professions by AI

Artificial intelligence has expanded its applicability across numerous fields, including the legal domain. From document analysis and management to legal research, prediction of court decisions, and automation of repetitive activities, these technologies present significant potential for increasing the efficiency of legal professions. However, at the current stage of development, the hypothesis of the complete replacement of legal professionals by artificial intelligence remains unjustified, being contradicted by ethical, technical, and legal considerations.

Despite notable progress, artificial intelligence continues to be marked by relevant technical limitations. AI-based systems operate through algorithms and datasets, making them susceptible to errors, distortions, or incomplete interpretations. Thus, although they can identify patterns or trends in prior case law, these systems are unable to capture the complexity, subtleties, and exceptions inherent in legal reasoning, as an experienced lawyer or judge can.

At the same time, there are legal impediments to the complete substitution of legal professionals by artificial intelligence. In most legal systems, lawyers are subject to legal and deontological obligations toward beneficiaries of legal services, such as confidentiality, loyalty, and professional diligence - obligations that automated systems cannot currently assume or guarantee. For instance, the obligation to maintain confidentiality is difficult to ensure absolutely through AI, given inherent cybersecurity risks. Moreover, in the event of

professional error, a lawyer's liability is personal and based on *intuitu personae* obligations, whereas identifying and assigning legal responsibility in the case of AI use raises significant difficulties.

Concerns regarding the regulation of artificial intelligence in legal practice are also present at the national level. In Romania, a legislative initiative has been promoted aimed at leveraging programming languages and digital technologies in activities specific to the legal profession.

In conclusion, artificial intelligence has the capacity to reshape multiple dimensions of the legal profession by optimizing processes, facilitating access to justice, and developing advanced tools for practitioners. Nevertheless, it must be understood as a support tool rather than a substitute for human reasoning. Value judgment, discernment, interpretation of legal norms, and ethical-moral evaluation remain essential attributes of the human factor, without which the exercise of legal professions cannot be conceived, at least at the current stage of technological development.

8. Conclusions

Digitalization and the use of artificial intelligence in notarial activity represent not only a global trend but also a practical necessity for adapting to the requirements of a digital society. The integration of information technologies, AI, and national electronic registers can significantly improve efficiency, access to information, and the security of notarial acts.

However, the adoption of these technologies must respect the fundamental principles of law, including data protection, decision transparency, and professional responsibility. Recent European regulations, such as the Artificial Intelligence Act, and existing personal data norms provide a reference framework for the responsible implementation of emerging technologies.

Digitalization and AI can transform notarial activity by increasing efficiency and accessibility. Nevertheless, they cannot replace legal discernment, professional responsibility, and the public authority of the notary. The implementation of digital technologies must be accompanied by clear regulations, adequate technical infrastructure, and a firm commitment to data protection and cybersecurity. International experiences can guide Romania in modernizing the notarial profession, provided that AI is used strictly as a support tool.

Ultimately, the future of digital notarial practice will depend on regulatory harmonization, efficient technical infrastructure, the professional training of notaries, and public trust in digital systems and artificial intelligence.

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BRIEF CONSIDERATIONS ON THE EUROPEAN UNION'S REGULATORY FRAMEWORK GOVERNING GENERAL- PURPOSE AI MODELS

Assist Professor BOGDAN Anca Viorica Ph.D.

*Assist. Professor Ph.D., "Dimitrie Cantemir" University of Târgu Mureș, Faculty of Law (ROMANIA)
Email: Anca.Bogdan@TarguMures.onmicrosoft.com*

Abstract

This study analyses the legal framework governing general-purpose artificial intelligence (GPAI) models under Regulation (EU) 2024/1689, as amended by the second set of implementing provisions that entered into force in August 2025, and in light of the Code of Practice on GPAI models adopted by the European Commission in July 2025. The study focuses on the legal qualification of GPAI models and GPAI models with systemic risk, the criteria and procedures for their designation, as well as the notification and review mechanisms applicable to such classification. Furthermore, the paper examines the substantive obligations imposed on providers and their authorised representatives, with particular regard to transparency requirements, compliance with Union copyright and related rights, and the duties relating to model safety and security. It also addresses the legal function of codes of conduct and the scope of the regulatory exemptions provided by the Regulation. The analysis argues that the regulatory architecture established by Regulation (EU) 2024/1689 strengthens legal certainty for economic operators while pursuing a normative balance between technological innovation, the protection of intellectual property rights, and the prevention of systemic risks associated with advanced AI models.

Keywords: EU AI Act, general-purpose AI models, accountability in AI systems, GPAI Code of Practice, European Commission guidelines.

Introductory Aspects

On August 2, 2025, the second set of rules of Regulation (EU) 2024/1689 on Artificial Intelligence came into force [1]. These rules include the provisions of Chapter III, Section 4, Chapters V, VII, XII, and art. 78, with the exception of art. 101.

On July 10, 2025, the European Commission adopted the final version of the Code of Practice on General Purpose AI (GPAI) models [2]. The primary objective being pursued by the Commission is to strengthen legal certainty for actors involved in the AI value chain, and to clarify the circumstances under which providers are required to implement the requirements of the regulation [3].

Without conducting an exhaustive analysis, this study seeks to examine the essential aspects of the legal regime for GPAI models as articulated in Chapter V of the Regulation. Chapter V of the Regulation (EU) 2024/1689 on AI, entitled "General Purpose AI Models," comprises four sections. Section I (art. 51-52) is devoted to the rules governing classification, establishing the

conditions that must be met for GPAI models to be classified as systemic risk models (art. 51), as well as the procedure to be followed should these conditions be met (art. 52). According to Section 2 (art. 53-54), providers of GPAI models are bound by a series of obligations (art. 53), and their authorized representatives are subject to a specific set of regulations (art. 54). Moreover, Section 3 (art. 55) delineates the obligations of providers of general-purpose AI models with systemic risk. Section 4 (art. 56) comprises a set of regulations pertaining to the development and implementation of codes of conduct.

Conceptual Delimitations

An analytical approach necessitates the elucidation of the concepts of "general-purpose AI model" and "general-purpose AI model with systemic risk", as defined by the Regulation and explained in the European Commission Guidelines of July 18, 2025 [4].

According to art. 3 para. (63) of the Regulation, a general-purpose AI model is defined as an AI model, including where such an AI model is trained with a large amount of data using self-supervision at scale, that displays significant generality and is capable of competently performing a wide range of distinct tasks regardless of the way the model is placed on the market and that can be integrated into a variety of downstream systems or applications, except AI models that are used for research, development or prototyping activities before they are placed on the market. The definition is founded upon the essential functional characteristics of a GPAI model, most notably generality and the capacity to adeptly execute a broad spectrum of discrete tasks [5]. It is common practice to train these models on extensive datasets utilising diverse methodologies, such as self-supervised, unsupervised, or reinforcement learning techniques. The deployment of GPAI models in the marketplace can be facilitated through various avenues, including the utilisation of libraries, application programming interfaces (APIs), direct download options, or the provision of physical copies. It should be noted that these models can undergo further modification or calibration, thereby facilitating their transformation into new models. A fundamental distinction exists between a GPAI model and an AI system; the former constitutes an integral component of the latter, which encompasses supplementary components, such as a user interface and the capacity to fulfil multiple functions. In consideration of the heterogeneity of capabilities and use cases inherent to GPAI, it becomes challenging to conceptualise a comprehensive catalogue of competencies and operations that a model must demonstrate or possess in order to ascertain its categorisation within the paradigm of GPAI models. However, the Commission puts forward the utilisation of computational resources employed during the model's training phase ("training compute"), quantified in FLOP, in conjunction with the model's typologies (modalities), to formulate a guideline criterion that delineates a model as a GPAI model. To illustrate, a model of this nature is one that has been trained on an extensive dataset of natural language (i.e., text) data. This data has been meticulously selected and extracted from various sources on the internet, among others, utilizing 10^{24} FLOP. Conversely, models that have been trained on natural language data using 10^{22} FLOP, yet lack the capability to competently perform a wide range of distinct tasks, cannot be classified within this category. Furthermore, those that are trained for a specific task, such as speech-to-text transcription, text-to-speech generation, image resolution enhancement, replacement of missing parts of an image, modelling of weather patterns or physical systems, those designed for chess or video games, etc., cannot be included in the category, even if the value of 10^{24} FLOP is utilised [6].

Art. 51 para. (1) of the Regulation delineates the circumstances under which a GPAI model poses a systemic risk, specifically when it satisfies one of the following conditions: it possesses high-impact capabilities that have been evaluated using suitable technical tools and methodologies, encompassing indicators and benchmarks. [point (a)] or has been designated following a decision by the Commission, either *ex officio* or subsequent to a qualified alert from the scientific group, as having capabilities or an impact equivalent to those referred to in point (a), taking into account the criteria set out in Annex XIII [point (b)]. It should be acknowledged that for a GPAI model to be designated as presenting systemic risk, it is sufficient to fulfil one of the afore-mentioned criteria. The relevant technical instruments and methodologies will be established by the Commission through the adoption of delegated acts.

The Commission's *ex officio* decision is to be made in cases where it is observed that an GPAI model fulfils the criteria for classification as presenting systemic risk, a fact that was previously either not known or not communicated to the Commission by the relevant provider. The qualified alert issued by the scientific group is regarded as an ancillary supervisory measure, complementing the monitoring activities conducted by the IA Office.

Moreover, art. 51 para. (2), of the Regulation delineates the meaning of the term "high impact capabilities" as employed in para. (1). Specifically, it pertains to instances where the cumulative volume of computation utilized to train the GPAI model, measured in floating point operations, exceeds 10^{25} . The rationale behind this assertion lies in the prevailing notion that the cumulative volume of computational resources utilised in the training of a GPAI model, quantified in terms of FLOP, is regarded as a pertinent indicator for the identification of high-impact capabilities.

Notification and Appeal Procedure

In the event that the condition referred to in art. 51 para. (1) point (a) of the Regulation is met, the provider is obligated to adhere to the procedure delineated in art. 52 para. (1), namely to notify the Commission of this fact. The notification must be submitted within two weeks of the requirement being met or of the date on which it is established that it will be met.

From the wording of the provisions of art. 52 para. (1), it follows that situations may arise in which the notification must be submitted before the moment when the training of the model is completed, where the provider can reasonably foresee that the requirement leading to the presumption that the model has high impact capabilities is reasonably likely to be met. It is imperative that the notification includes all the information necessary to demonstrate that the relevant requirement has been fulfilled. According to the Commission's recommendation regarding the information to be included in the notification, aspects such as the volume of computational resources estimated by the supplier as triggering the notification obligation, reported in FLOP and with two significant digits, must be included (e.g., 2.3×10^{25} FLOP), and an elaboration on the methodology employed to estimate this volume of computational resources, encompassing the techniques employed for approximations in circumstances where precise information is not available.

Para. (2) of art. 52 of the Regulation establishes the procedure to be followed for contesting the classification. This pertains to circumstances where the criteria outlined in art. 51 para. (1) point (a) has been fulfilled, yet the model is deemed to not pose systemic risks. In such instances, providers are obligated to present sufficiently substantiated arguments to the Commission, thereby demonstrating the afore-mentioned aspects. Such scenarios emerge notably when the notification was precipitated by the supposition that the model possesses high impact capabilities, yet the provider deems this supposition to be unwarranted in regard to its

model. The information that providers are expected to incorporate within their arguments pertains to the capabilities attained or projected by the model, including in the form of actual or estimated benchmark test results, as well as any other pertinent information, such as its architecture, the number of parameters, the number of training examples, input and output modalities, intended uses of the tools and anticipated contextual length, data selection and processing techniques, training techniques. It should be acknowledged that referring to these arguments does not suspend the obligations incumbent on entities in their capacity as providers of AI models that pose systemic risk. Following the analysis, the Commission may accept or reject the arguments. Subject to the terms of acceptance, the AI model will no longer be regarded as posing systemic risk, and the provider will consequently be exempt from the obligations established for such cases. Conversely, in the event of rejection, the model will be confirmed as posing systemic risk, and the provider will be subject to the specific tasks.

In circumstances where the designation was assigned according to the conditions outlined in art. 51 para. (1) point (b) of the Regulation, providers are granted the possibility to appeal the classification decision. According to art. 52 para. (5) of the afore-mentioned legislative act, a request for reassessment may be submitted no earlier than six months after the date of the designation decision. The appeal must encompass a series of objective, detailed, and novel reasons that have emerged subsequent to the designation decision. In the event that, subsequent to the reassessment, the Commission opts to uphold the designation of a given model as presenting systemic risks, providers may submit a request for reexamination, with the earliest possibility being six months after the afore-mentioned decision.

Obligations of Entities Engaged in the Development of GPAI Models

As previously indicated, the primary responsibilities of GPAI model providers are delineated in art. 53 and 54 of the Regulation, while those pertaining to the providers of GPAI models with systemic risks are specified in art. 55. The afore-mentioned obligations have been established for the purpose of ensuring transparency, respect for intellectual property rights, and the safety and security of models.

In order to analyze the obligations of providers, it is imperative to first delineate the term "provider". Therefore, it is essential to corroborate the provisions of art. 3 para. (3) with those of art. 2 para. (1) point (a) of the Regulation. The initial legal provision stipulates the definition of a "provider" as a natural or legal person, public authority, agency or other body that develops an AI system or a general-purpose AI model or that has an AI system or a general-purpose AI model developed and places it on the market or puts the AI system into service under its own name or trademark, whether for payment or free of charge. According to art. 2 para. (1) point (a) of the afore-mentioned legislative act, the Regulation in question is applicable to providers who place on the market or put into service AI systems or place on the market general-purpose AI models in the Union, irrespective of whether those providers are established or located within the Union or in a third country. Therefore, prior to the commercialization of AI models within the Union market, suppliers originating from third countries are obligated to appoint an authorized representative established within the Union, as stipulated in art. 54 of the Regulation. This designation must be formalized through a written mandate, thereby ensuring compliance with the stipulated regulations. The European Commission, in its guidelines, provides a number of examples pertaining to AI model providers, taking into consideration multiple potential scenarios:

- in the event that actor A develops an GPAI model and subsequently places it on the market, actor A is considered the provider;
- in the event that actor A has an GPAI model developed on its behalf by actor B and actor A subsequently places it on the market, actor A is considered the provider;
- in the event that actor A develops a GPAI model and subsequently uploads it to an online repository that is hosted by actor C, then actor A is deemed the provider;
- in the event that a collaboration or consortium has a GPAI model developed for it by different individuals or organizations and places it on the market, then, as a general rule, the coordinator of the collaboration or consortium is considered the provider. Alternatively, the collaboration or consortium may be regarded as the provider.

The classification of actors as providers of GPAI models must be evaluated on a case-by-case basis [6].

The transparency obligations are meticulously delineated in art. 53 para. (1) points (a), (b) and (d) and in Annexes XI and XII to the Regulation.

The obligation laid down in art. 53 para. (1) point (a) concerns the duty of providers of AI systems to prepare and continuously update the technical documentation of the model, including the processes relating to its training and testing, as well as the results of its evaluation, which must contain at least the information specified in Annex XI, for the purpose of making such documentation available, upon request, to the AI Office and the competent national authorities.

The Code of Practice, in the chapter on transparency, stipulates that the update should be prepared in such a manner as to highlight the major changes that have occurred in the initial documentation. The Code of Good Practice, in the chapter on transparency, stipulates that the update should be prepared in such a manner as to highlight the major changes that have been made to the initial documentation, including those relating to the updated version of the same model, including the obligation to maintain previous versions of the documentation for a period of 10 years following the model's release onto the market.

The obligation delineated in art. 53 para. (1) point (b) pertains to the mandate of providers of GPAI systems to develop, update, and disseminate information and documentation intended for providers of AI systems who seek to integrate the GPAI model into their AI systems. It is imperative that the information provided enables AI system providers to achieve a comprehensive understanding of the capabilities and limitations of the GPAI model [i] and must contain at least the elements set out in Annex XII [ii]. The Code of Practice stipulates that signatories, when introducing a GPAI model into the market, are obligated to publicly disclose the contact information for the AI Office and for downstream providers via their website or via alternative appropriate means of disclosure in order to be able to request access to the relevant information contained in the model documentation, or other necessary information. Signatories are encouraged to consider whether the documented information can be disclosed, in whole or in part, to the public in order to promote public transparency. This would also be in accordance with the obligation set out in art. 53 para. (1) point (d), which stipulates that a sufficiently detailed summary of the content used to train the AI model must be prepared and made available to the public, in accordance with a template provided by the AI Office.

Within the category of obligations relating to the observance of intellectual property rights are included those laid down in art. 53 para. (1) point (c), which impose on providers of GPAI systems the duty to implement a policy aimed at ensuring compliance with Union law on copyright and related rights and, in particular, at identifying and complying, including on the basis of the state of the art of technology, with any reservation of rights expressed pursuant to

art. 4 para. (3) of Directive (EU) 2019/790 [3]. The Code of Practice, in the chapter on intellectual property rights, recommends the adoption of a copyright policy that requires signatories to adopt at least five measures: to develop, update, and implement a policy on the enforcement of intellectual property rights (which has to be made available to the public in summary form); to ensure that any content reproduced and extracted is both copyright-protected and legally accessible when searching the internet; to identify and respect rights reservations when searching the internet; to reduce the risk of producing results that infringe intellectual property rights; to establish a contact address and facilitate the possibility of filing complaints.

Art. 54 para. (3) establishes a series of obligations for the authorized representatives of GPAI model providers. These obligations include verifying that the technical documentation specified in Annex XI has been drawn up and that the provider has fulfilled all the obligations referred to in art. 53 and, where applicable, in art. 55 [point (a)]; to retain the documentation and to maintain the contact information for the provider who has appointed the authorized representative, for a period of ten years following the placement of the GPAI model on the market, in order to be made available upon request by the IA Office or the relevant national authorities [point (b)]; to provide the IA Office, on a reasoned request, all pertinent information and documentation, including that specified in point (b), in order to substantiate its compliance with the obligations stipulated in the Chapter [point (c)]; to cooperate with the AI Office and the relevant authorities, in accordance with a reasoned request, pertaining to any actions initiated by these bodies concerning an AI model, including the cases where the model is integrated into AI systems that have been placed on the market or otherwise put into service within the Union [point (d)].

The safety and security obligations of models are delineated in art. 55 para. (1) points (a)-(d) and art. 56 para. (5) of the Regulation. Art. 55 para. (1) establishes a series of additional duties to those mentioned above which apply only to providers of AI models with systemic risk. Art. 56 para. (5) stipulates the obligation of the AI Office to oversee and ensure that signatories to codes of conduct report to it information pertaining to the implementation of the commitments and measures adopted, as well as the results achieved.

The Regulation also stipulates a number of exceptions to the fulfilment of the aforementioned obligations, delineating the terms and conditions under which these exceptions apply [3]. These exceptions are delineated in art. 53 para. (2) and 54 para. (6) of the Regulation.

Entities engaged in the development of GPAI models can demonstrate compliance with the obligations delineated in art. 53 para. (1) and 55 para. (1) of the Regulation by adhering to and complying with the provisions of codes of conduct that have been assessed as appropriate by the AI Office and the Council [5].

Conclusions

The implementation of the recent amendments to the Regulation (EU) 2024/1689 serves to fortify the European legal apparatus governing GPAI models and the ones with systemic risks. The delineation of these concepts, accompanied by the stipulated notification and appeal procedures, fosters enhanced legal predictability for providers. Transparency obligations, respect for intellectual property rights, and model safety are three mechanisms which have been implemented with the aim of protecting users and reducing systemic risks.

The code of conduct and exceptions for open-source models also support innovation; this is achieved by seeking to maintain a balance between security and technological development.

Academic Integrity Statement on the Use of AI

The use of artificial intelligence (AI) as a valuable tool in the preparation of this scientific paper is hereby acknowledged. Specifically, the ChatGPT 5.0 model was employed to support the legislative documentation process, assist in organizing ideas, enhance the clarity of the text, and facilitate translation. Nevertheless, I assume complete accountability for the substance and assertions articulated in the present document.

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TRANSPARENCY IN THE RECRUITMENT OF THE WORKFORCE ASSISTED BY ARTIFICIAL INTELLIGENCE. EUROPEAN FRAMEWORK AND NATIONAL PERSPECTIVES. THE ITALIAN EXAMPLE AND INITIATIVES IN ROMANIA

Assist. Professor Lăcrămioara-Ionela COJOCARIU Ph.D. Stud.

"Dimitrie Cantemir" University of Târgu Mureș, Faculty of Law, Romania
Corresponding author: Lăcrămioara-Ionela Cojocariu: lacramioara900@gmail.com

Abstract

The idea of the study started from the new regulations that have emerged both at the European Union level and within the Member States regarding artificial intelligence. These regulations are also relevant in the context of employment relations, especially in the recruitment stage of new employees. The study aims to answer the question "what and how much should be explained to a candidate when artificial intelligence is used in recruitment?". Among others, relevant provisions from the Regulation on artificial intelligence (2024/1689), the General Data Protection Regulation (2016/679), Italian Law number 132/2025 and certain legislative projects submitted to the Romanian Parliament to date are analysed. According to the provisions of Regulation (EU) 2024/1689, artificial intelligence systems used in recruitment are classified as high-risk. Employers are obliged to inform both workers' representatives and workers about the use of these artificial intelligence systems in the recruitment process. Therefore, transparency under the Artificial Intelligence Regulation must not only be formal, but real. Selection must be subject to effective human review, and the documentation that formed the basis of the employment decision must be verifiable. In Italian law, Law No. 132/2025 operationalizes this transparency in employment relationships. Domestically, in Romania, the European framework is applied as a priority, and legislative initiatives on artificial intelligence are still at various stages, without there being, to date, a law dedicated to this matter.

Keywords: artificial intelligence (AI), recruitment, employee, employer, high-risk.

1. Introduction

Artificial Intelligence (AI) has become a topic of great interest in all areas of social, economic, cultural and political life. Relatively recently, Regulation (EU) 2024/1689 of the European Parliament and of the Council (13 June 2024) laying down harmonised rules on artificial intelligence and amending Regulations (EC) No 300/2008, (EU) No 167/2013, (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1139 and (EU) 2019/2144 and Directives 2014/90/EU, (EU) 2016/797 and (EU) 2020/1828 (the Artificial Intelligence Regulation, hereinafter referred to as the "AI Regulation") [1] was adopted. This regulation approaches artificial intelligence from a perspective based on avoiding "risks" through the use of AI. It

distinguishes between four categories of risk [2], namely: unacceptable, high, limited and minimal [3].

As stated in the very first recital, the purpose of adopting this Regulation is to improve the functioning of the internal market by establishing a uniform legal framework for AI, to promote the adoption of trustworthy and human-centric artificial intelligence (AI), while ensuring a high level of protection of health, safety, fundamental rights enshrined in the Charter of Fundamental Rights of the European Union, and to support innovation. At the same time, the Regulation establishes: prohibitions, specific requirements for high-risk AI systems, harmonised transparency rules for certain AI systems, rules for general-purpose AI models, rules on market monitoring and surveillance, and a governance and enforcement system [Article 1(2)].

AI [4] systems used in the context of employment, worker management and access to self-employment are classified as high-risk (Annex III, point 4 of the RIA). Therefore, AI systems used in the recruitment of future employees present a high level of risk, in particular in that they may influence whether or not a candidate is hired for a particular position.

In the recruitment process, the RIA obliges implementers [5] (in this case, employers) to inform workers' representatives and workers that they will be involved in the use of high-risk AI systems [art. 26 para. (7)]. This leads to the employer's obligation of transparency towards the candidate [art. 26 para. (11)], which must be real, not formal, so that the candidate is informed about the use of automated assessment tools. This also leads to the research question that we aim to answer in this paper, namely: what and how much should be explained to a candidate when AI is used in recruitment?

In the context of employment, AI can be used to promote job opportunities, to narrow the pool of candidates by eliminating less qualified candidates from consideration, to assist human recruiters [6] by maintaining contact with candidates, scheduling interviews or even conducting them [7]. Existing examples include, for example, “Vera” or “Tengai”. Vera is an application that finds suitable CVs online, calls candidates and conducts interviews (via voice or video). Tengai is an AI assistant developed to objectively select candidates and provides structured data, which makes it possible to identify candidates with the right skills. Tengai is also able to conduct online interviews [8].

We note that, at present, the RIA is partially applied. According to art. 113, its provisions shall apply from 2 August 2026. By way of exception, Chapters I and II shall apply from 2 February 2025, Chapter III Section 4, Chapter V, Chapter VII, Chapter XII and Art. 78 shall apply from 2 August 2025, with the exception of Art. 101. Also, Art. 6 para. (1) and the corresponding obligations in the Regulation shall apply from 2 August 2027.

2. European Regulatory Framework on Transparency in AI-assisted Workforce Recruitment

Recruitment of labour force expressly falls within the scope of high-risk AI systems. According to Annex III point 4 of the Regulation, AI systems “intended to be used for the recruitment or selection of natural persons, in particular for placing specifically targeted job advertisements, for analysing and filtering applications for jobs and for assessing candidates (a); (...) for taking decisions affecting the terms of employment relationships, for promoting and terminating employment-related contractual relationships, for allocating tasks on the basis of individual behaviour or personal traits or characteristics or for monitoring and evaluating the performance and behaviour of persons in such relationships (b)” are classified as high-risk. In

other words, if AI is used in any of the operations listed in point (a) a) (recruitment, selection, placement of specifically targeted job advertisements, analysis and filtering of applications, assessment of candidates) or b) (task allocation, monitoring and performance evaluation), then, according to the RIA, it is classified as representing a high degree of risk.

From the rule established by art. 6 par. (2) of the RIA, there are also exceptional situations, established by par. (3) of the same article. Specifically, if the AI-system is intended for one of the 4 situations regulated in letters a) - d), that AI-system will not be considered as presenting a high degree of risk. The first situation refers to the performance of a limited procedural task, the second to the improvement of the outcome of a human activity already completed, the third to the detection of decision-making patterns or deviations from previous decision-making patterns and is not intended to replace or influence the human assessment already completed, without an appropriate review, and the fourth is the performance of a preparatory task for a relevant assessment for the purposes of the use cases listed in Annex III. However, according to par. (3) of art. 6 "an AI-system referred to in Annex III shall always be considered as presenting a high degree of risk if it creates profiles of natural persons".

"Profiling" is defined in Regulation (EU) 2016/679 [9] of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation) [hereinafter referred to as "GDPR"] in Article 4(4) as meaning "any form of automated processing of personal data consisting of the use of personal data to evaluate certain personal aspects relating to a natural person, in particular to analyse or predict aspects concerning that natural person's performance at work, economic situation, health, personal preferences, interests, reliability, behaviour, location or movements". In such a situation, the AI system always remains qualified as posing a high risk, regardless of the exceptions provided for in Article 6(3)(a). a)–d).

At the heart of the transparency obligation in the field of AI-assisted recruitment is Article 26 of the RIA. On the one hand, paragraph (11) of Article 26 provides for the obligation of implementers to inform data subjects when an AI system is used in the areas set out in Annex III, including when such a system is used in the recruitment, selection or assessment of candidates. On the other hand, paragraph (7) of Article 26 establishes the obligation of implementers to inform both workers' representatives and workers if high-risk AI systems are used. In other words, the employer is not allowed, during the course of the employment relationship, to introduce such systems neither to candidates nor to persons already employed.

According to Art. 26 para. (2) RIA, high-risk AI systems must be subject to effective human supervision. The wording used by the European legislator, ("human supervision"), leaves no room for interpretation, in the sense that this supervision could in turn be exercised by another algorithm. The person who is to carry out the supervision must have the necessary competence, training and authority, as well as the necessary support (from the employer). In practice, the supervisor could affirm or deny an outcome proposed by the AI system. In this context, the provisions contained in the General Data Protection Regulation in Art. 22 are relevant, which provide for the right of the data subject (in this case, the candidate) "not to be subject to a decision based solely on automated processing, including profiling, which produces legal effects concerning the data subject or similarly significantly affects him or her".

It can be concluded that, through these cumulative obligations established by the RIA (information, effective human supervision, use of adequate and reliable data and existence of verifiable records), the European legislator does not only aim for formal transparency, but real

transparency, making it possible for the candidate to challenge a decision generated exclusively by automated means.

Art. 50 RIA, with the marginal name “transparency obligations for providers and implementers of certain AI systems”, is relevant for this paper especially in light of the fact that, in the recruitment process, employers may use emotion recognition or biometric classification systems [art. 50 para. (3)], an aspect on which candidates must be informed. Candidates must also be informed about the fact that they are interacting with an AI system (for example, a chatbot [10] available on a recruitment website) [art. 50 para. (1)] and about the fact that they are presented, when appropriate, with content generated or altered by means of AI (images, video recordings, etc.) [art. 50 para. (2)].

In addition to the transparency obligations established by the RIA, the relevant ones provided for by Regulation (EU) 2016/679 must be added, which is applicable whenever, in the recruitment process, personal data of candidates are taken over [11]. The provisions to which we refer are those of art. 13, art. 14, art. 22, art. 35 and art. 36 of the GDPR.

Art. 13 and 14 of the GDPR regulate the obligation of information, which falls on the employer, in its capacity as controller [12] of personal data [13]. There are two ways in which the employer comes into possession of the candidate's data, under the terms of the General Data Protection Regulation. The first way is when the data is collected directly from the candidate (for example, when he uploads his CV [14] to an online recruitment platform). The employer must clearly communicate to the candidate aspects such as who the controller is, for what purpose the data are used, the legal basis for the processing, the categories of data recipients, the period for which the data will be stored, as well as the rights of the candidate (art. 13 GDPR). The second way is to obtain the data from other sources (for example, through a recommendation or from an online platform intended for finding a job). The information that the employer must communicate to the candidate is, in principle, the same, with the addition of the source from which the data were taken. This information must also include the mention that an AI system intervenes in the selection process, where applicable, as well as a description of its general functioning, in the candidate's understanding.

Art. 22 of the GDPR enshrines the right of the data subject not to be subject to “a decision based solely on automated processing, including profiling, which produces legal effects concerning the data subject or similarly significantly affects him or her” [paragraph (1)]. If we apply this provision to recruitment, we find that the automatic rejection of an application, solely on the basis of the result generated by an AI system, is, as a rule, prohibited. We note that, under both Art. 22 of the GDPR and Art. 26 of the RIA, the European legislator establishes the need for real human supervision to examine the result proposed by the AI system. The lack of this human intervention could lead to automatically generated decisions without appropriate safeguards, which would contravene both the GDPR and the RIA.

Art. 35 of the GDPR is relevant in this context, as it obliges the controller to carry out an assessment of the impact of the processing on the protection of personal data [15], where the processing is likely to result in a high risk to the rights and freedoms of natural persons [paragraph (1)]. The use of high-risk AI systems in the recruitment process may trigger this obligation, as it involves the assessment of candidates and the creation of profiles for access to a job [16]. The minimum content of the assessment is set out in Art. 35 para. (7) of the GDPR and comprises, at least: a systematic description of the intended processing operations and the purposes of the processing, including, where applicable, the legitimate interest pursued by the controller [paragraph (7)(a)]; an assessment of the necessity and proportionality of the processing operations in relation to those purposes [paragraph (7)(b)]; an assessment of the

risks to the rights and freedoms of data subjects referred to in paragraph (1) [paragraph (1) 7 letter (c)]; the measures envisaged to address the risks, including safeguards, security measures and mechanisms designed to ensure the protection of personal data and to demonstrate compliance with the GDPR [par. 7 letter (d)]. In essence, through this assessment obligation, the GDPR is not limited to a formal information of the candidate, but protects him substantially: the employer must identify risks in advance (such as erroneous or discriminatory exclusion from the selection process) and be able to show what concrete measures it is taking to prevent them [17].

Art. 36 of the GDPR, with the marginal name "prior consultation", regulates the mechanism of prior consultation of the supervisory authority. This mechanism is to intervene if, following the impact assessment provided for in Art. 35 of the GDPR, the processing of data would continue to generate a high risk for the rights of candidates. The controller is obliged to address the authority before the start of the processing [Art. 36 para. (1)]. The supervisory authority [18], provides advice to the controller or may use any of its powers regulated in Art. 58 of the GDPR [19] to ensure the compliance of the data processing with the GDPR, including by ordering corrective measures, imposing compliance with certain conditions, limiting or suspending the processing or, in serious cases, prohibiting it.

Therefore, the obligation of transparency in recruitment is not limited to informing the candidate provided for in Art. 26 para. (11) and Art. 50 of the RIA, but is doubled by the information obligations provided for in art. 13 and 14 of the GDPR, the prohibition of the future employee being subject to an employment/non-employment decision generated exclusively automatically (art. 22 of the GDPR) and the obligation to assess and, if necessary, declare the high risk before using the respective AI system (art. 35 and 36 of the GDPR). All these steps are to guarantee real transparency, not just formal one, which would allow the candidate to understand, ask questions and, if necessary, challenge the selection result.

3. The Role of National Legislation in the Application of RIA. The Italian Example

Pursuant to Art. 288(2) TFEU [20], regulations have general applicability, being binding in their entirety and directly applicable in each Member State of the European Union [21]. This statement is also found in Art. 113 of the RIA, the final sentence. However, after the adoption of a regulation [22], implementing measures (institutional organisation, procedures, sanctions) may be necessary at Member State level, without modifying the content of the Union act. For example, after the entry into force of the GDPR, in Romania Law no. 102/2005 on the establishment, organisation and functioning of the National Supervisory Authority for the Processing of Personal Data was republished to ensure the internal framework for implementation in accordance with the Regulation.

And in the case of the RIA, the Member States come to operationalise its provisions. Moreover, this operation is imposed by the RIA itself. For example, Art. 28(1) (1) of the RIA provides that "each Member State shall designate or establish at least one notifying authority responsible for setting up and carrying out the necessary procedures for the assessment, designation and notification of conformity assessment bodies and for their monitoring". Such national measures concern the implementation of the Regulation (institutional and procedural organisation), not its transposition.

From this perspective, Italian Law No. 132/2025 on artificial intelligence [23] must also be understood, not as a transposition of the RIA, but as an implementing and supplementing act at national level. According to Art. 1(2) of this law, its provisions are to be interpreted and applied

in accordance with the RIA. Furthermore, Art. 2 states that the definitions given in the RIA (Art. 3 "definitions") will also be used with regard to Italian law.

In Italian law, transparency in the use of artificial intelligence in employment relationships is built on two normative levels: on the one hand, Law no. 132/2025 on artificial intelligence and, on the other hand, art. 1-bis of Legislative Decree no. 152/1997 [24]. The former establishes the general principles on the use of AI in employment, including in recruitment, in accordance with the RIA, and the latter contains detailed information obligations when, in relation to the hiring and management of workers, decision-making or monitoring systems are used.

Art. 11 of Law no. 132/2025 represents the central point of the regulation in the field of employment, having the marginal name "provisions on the use of artificial intelligence in employment matters" ("disposizioni sull'uso dell'intelligenza artificiale in materia di lavoro"). According to par. 1 of art. 11 of Law no. 132/2025, AI can be used to improve working conditions, protect the physical and mental integrity of workers, and increase the quality and productivity of work.

Art. 11 paragraph (2) of Law no. 132/2025 specifies that the use of AI in employment relationships must be safe, reliable and transparent. At the same time, its use must respect human dignity and not violate the confidentiality of personal data. As regards transparency, paragraph 2 of art. 11 expressly states the employer's obligation to inform workers about the use of AI, making direct reference to the detailed regime in Legislative Decree no. 152/1997 (art. 1-bis). In other words, Law no. 132/2025 extends the existing legislative framework on information contained in Legislative Decree no. 152/1997 also with regard to AI [25].

Art. 1-bis of Legislative Decree no. 152/1997 has the marginal title "additional information obligations in the case of the use of automated decision-making or monitoring systems" ("Ulteriori obblighi informativi nel caso di utilizzo di sistemi decisionali o di monitoraggio automatizzati"). Even though art. 1-bis was introduced in 2022, it is in line with the provisions on transparency in AI-assisted recruitment provided for by the RIA.

As regards the actual content of the information obligation, art. 1-bis expressly establishes what must be communicated to the employee (or future employee) when the employer uses AI systems in decision-making or monitoring processes. Thus, the employer must indicate at least: the aspects of the employment relationship affected by the use of the system (for example, candidate selection, assignment of tasks or performance evaluation); the purposes and objectives for which the system is used; the operating logic of the system; the categories of data used and the main parameters on which the system is programmed or "trained", including any performance evaluation mechanisms; the control measures established for automated decisions, correction procedures, and the person responsible for the quality management system; the level of accuracy, robustness and cybersecurity of the system and the indicators used to measure these parameters, as well as the potential discriminatory impact of these indicators [paragraph (2) letters a)-f) of art. 1-bis].

Paragraph (6) of art. 1-bis of Legislative Decree no. 152/1997 once again underlines the "real" dimension of transparency: the information and data provided for in paragraphs (1)-(5) must be communicated in a transparent manner, in a structured format, commonly used and machine-readable, and not simply recorded in a formal document that is difficult to understand. The same information and data must also be made available to the trade union representatives of the unit or, in their absence, to the territorial offices of the most representative trade unions at national level, and, upon request, can also be requested by the Ministry of Labor and Social Policies, respectively the National Labor Inspectorate. In this way, transparency is not only an

obligation in relation to the employee individually, but also becomes an instrument of collective and institutional control over the use of automated systems, including AI, in employment relations.

In contrast to the Italian example, in Romania there is, so far, no special law in force regarding AI, let alone one that expressly provides for how the obligation of transparency in the field of employment relations is achieved.

The regulatory framework applicable to our country is, mainly, the legislation at the European Union level (especially the RIA and the RGPD), the regulations of the Labor Code [26], those regarding non-discrimination and the provisions of Law no. 102/2005. In addition to these, there are also some strategic documents, such as the National Strategy in the field of artificial intelligence 2024–2027 [27].

In context, we mention that, starting with 2023, there are a series of legislative projects regarding the regulation of AI, such as: “Draft Law on the responsible use of technology in the context of the deepfake phenomenon [28]”; “Legislative Proposal on Artificial Intelligence [29]”; “Draft Law on the responsible use of artificial intelligence [30]”. There was also a legislative project that aimed to regulate AI in the context of its use in online electoral campaigns [31]. From the examination of these legislative proposals, it emerges that employment relations are not treated as a distinct object of regulation, and transparency within employment relations (especially in the AI-assisted recruitment process) is not explicitly addressed in any of the initiatives. The only specific reference to the labor field is included in the 2024 legislative draft, in art. 9: “the use of Artificial Intelligence for the automation of the flow of human resources within any type of organization is prohibited, as well as the use of biometric data of individuals, other than for the purposes of preventing and detecting crimes.”

Conclusions

Starting from the research question of *what and how much should be explained to a candidate when artificial intelligence is used in recruitment?* the analysis showed that, at European level, the RIA and the GDPR already configure a relatively clear framework. On the one hand, the RIA qualifies AI systems used in recruitment and employment management as high-risk systems and subjects them to increased obligations of transparency and human supervision, while, on the other hand, the GDPR complements this framework with rules on information to the data subject, automated decisions and data protection impact assessment.

Regarding transparency in recruitment, the RIA is, broadly speaking, clear enough to establish a minimum standard: the candidate must be informed that AI is being used, at what stage of the process it intervenes and what his or her rights are, a standard complemented by the GDPR rules on information, automated decisions and impact assessment. However, the regulation remains a general framework and does not say “how” this information looks in practice, nor what procedural guarantees must exist at national level. Italy has chosen to detail these aspects through Law no. 132/2025 and by referring to art. 1-bis of Legislative Decree no. 152/1997, transforming transparency into a concrete and verifiable mechanism. Romania will have to decide, as the RIA becomes fully applicable, whether to remain at this minimal level or whether to introduce, in turn, more detailed internal rules on the use of AI in recruitment and the obligation to inform the candidate

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- [3] See M. Ebers, Truly Risk-based Regulation of Artificial Intelligence How to Implement the EU’s AI Act, in European Journal of Risk Regulation, No 2/2025, pp. 684-703 [available at: <https://doi.org/10.1017/err.2024.78> (accessed 20 October 2025)].
- [4] According to Article 3(1) of the RIA, “AI system means a machine-based system that is designed to operate with different levels of autonomy and that may exhibit adaptability after implementation, and that, pursuing explicit or implicit objectives, infers, from the input data it receives, how to generate outputs such as predictions, content, recommendations or decisions that can influence physical or virtual environments”.
- [5] For the purposes of Article 3(4) of the RIA, “implementer means a natural or legal person, public authority, agency or other body that uses an AI system under its authority, except where the AI system is used in the course of a personal, non-professional activity”.
- [6] In the current meaning of the modern Romanian language, the term “recruiter” means “a person who made recruitments in the army” or “a person who recruits members for a party, for an association” [see Dex online, available at the web address: <https://dexonline.ro/definitie/recrutator> (accessed on October 22, 2025)]. In the context, by recruiter we mean a person who deals with the recruitment of employees.
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- [8] Idem.
- [9] The GDPR was published in OJEU Series L 119/1 of June 4, 2016.
- [10] Chatbots are computer programs built to interact with a human interlocutor, for example through incoming messages. For more details on the notion of chatbot, see Przegalinska, A., State of the art and future of artificial intelligence, European Parliament, Policy Department for Economic, Scientific and Quality of Life Policies, Briefing PE 631.051, February 2019, available at: https://www.europarl.europa.eu/RegData/etudes/BRIE/2019/631051/IPOL_BRI%282019%29631051_EN.pdf, accessed on 2 December 2025.
- [11] For the purposes of the GDPR, “personal data means any information relating to an identified or identifiable natural person (data subject); an identifiable natural person is one who can be identified, directly or indirectly, in particular by reference to an identifier such as a name, an identification number, location data, an online identifier or to one or more factors specific to that natural person’s identity. his/her physical, physiological, genetic, mental, economic, cultural or social data” (Art. 4, point 1).
- [12] “Controller means the natural or legal person, public authority, agency or other body which, alone or jointly with others, determines the purposes and means of the processing of personal data; where the purposes and means of the processing are determined by Union or national law, the controller or the specific criteria for his/her designation may be laid down in Union or national law” (Art. 4, point 7 of the GDPR).
- [13] For the information obligations provided for in Art. 13–14 GDPR, see former Article 29 Working Party, Guidelines on transparency under Regulation 2016/679 (WP260 rev.01), guidelines subsequently approved by the European Data Protection Board (EDPB), available at the web address: <https://ec.europa.eu/newsroom/article29/items/622227/en>, accessed on 30 October 2025.
- [14] *Curriculum vitae* means “Brief autobiography (written) that includes data regarding studies, professional training, career and family situation” (see the web page: <https://dexonline.ro/definitie/curriculum+vitae>, accessed on November 30, 2025).
- [15] The so-called DPIA (Data Protection Impact Assessment, in Romanian: Evaluarea impactului supra protecției data). A DPIA is a process designed to describe the processing, assess its necessity and proportionality and help manage the risks to the rights and freedoms of natural persons resulting from the processing of personal data by assessing them and determining measures to address them. DPIAs are important tools for accountability, as they help controllers not only to comply with the GDPR requirements, but also to demonstrate that appropriate measures have been taken to ensure compliance with the Regulation (see also Art. 24 of the RGPD). In other words, a DPIA is a process of building and demonstrating compliance. For details on DPIA, see Art. 29 Data Protection Working Party, Guidelines on Data Protection Impact Assessment

- (DPIA), WP248 rev.01, 4.10.2017, Guidelines approved by the European Data Protection Board, p. 4-5 [Guidelines available at: <https://ec.europa.eu/newsroom/article29/items/611236> (accessed 1 November 2025)].
- [16] Automated profiling is involved in the selection process which uses, for example, the algorithm that selects the CVs of candidates. This generally happens at the initial stage of the recruitment process, to create a shortlist of candidates for interview. The algorithm scans the CVs of candidates for keywords and other information that is believed to be correlated with successful employment, such as experience, job titles, previous employers, universities and qualifications. The system then creates a structured profile of the candidate, and all candidates are assessed and ranked. Depending on the company's practices, all profiles may be subsequently checked by humans or the company may focus exclusively on candidates with a higher rank [for some details, see E. Lacková, *Fragility of pre-contractual labour relations in the light of algorithmic recruitment*, in *Diritti Lavori Mercati International*, No. 2/2022, p. 78 et seq. (available at <chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.ddllmm.eu/wp-content/uploads/2022/12/02-2022int-03.3-Lackova.pdf>, accessed on 29 November 2025)].
- [17] See recitals (75) and (84) of Regulation (EU) 2016/679; Art. 29 Data Protection Working Party, Guidelines on Data Protection Impact Assessment (DPIA), op. cit., pp. 4-6.
- [18] In Romania, the competent authority is the National Authority for the Supervision of Personal Data Processing (ANSPDCP), which was established by Law no. 102/2005 (published in the Official Journal no. 391 of 9 May 2005 and republished in no. 947 of 9 November 2018).
- [19] According to art. 58 of the GDPR, the powers of the supervisory authority are grouped into 3 categories: investigative powers (paragraph 1), corrective powers (paragraph 2) and authorization and advisory powers (paragraph 3). In addition, Member States have the possibility to add new powers through national legislation (paragraph 6).
- [20] The Treaty on the Functioning of the European Union (TFEU) was established by the Treaty of Lisbon, signed on 13 December 2007 and entered into force on 1 December 2009 (published in OJEU C 326/172 of 26 October 2012).
- [21] The other types of legal acts adopted by the institutions of the European Union are: directives, decisions, recommendations and opinions (see Article 288(1) TFEU).
- [22] Unlike directives, which are binding upon each Member State to which they are addressed as to the result to be achieved, leaving to the national authorities the choice of form and methods (see Article 288(3) TFEU).
- [23] Law No. 123 of 23 September 2025 (“disposizioni e deleghe al Governo in materia di intelligenza artificiale”) was published in *Gazzetta Ufficiale* No. 223 of 25 September 2025 (see web address: <https://www.gazzettaufficiale.it/eli/id/2025/09/25/25G00143/sg>, accessed on 16 November 2025).
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- [27] Approved by Government Decree no. 832/2024 (published in the Official Gazette no. 730 of 25 July 2024). The Strategy is available at the web address: <https://sgg.gov.ro/1/wp-content/uploads/2024/07/ANEXA-1-10.pdf> (accessed on 22 November 2025).
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- [29] PL-x no. 336/2024 is available at the web address: https://www.cdep.ro/pls/proiecte/upl_pck2015.proiect?idp=21650&prn=1 (accessed on 21 November 2025).

The first chamber notified is the Senate, which also rejected the legislative proposal. The project is currently in the Chamber of Deputies, in the “report submitted; to be put on the agenda” stage, which is also the decision-making chamber.

[30] PL-x no. 184/2025 is available at the web address: https://cdep.ro/pls/proiecte/upl_pck2015.proiect?cam=2&idp=22396&prn=1 (accessed on November 21, 2025). The first chamber notified is the Senate, which sent the legislative proposal to the Chamber of Deputies. The project is currently in the Chamber of Deputies, in the “committees” stage (in preparation for opinions and report), which is also the decision-making chamber.

[31] [PL-x no. 154/2025, Legislative proposal to amend Law no. 370/2004 regarding the election of the President of Romania is available at the following website: https://www.cdep.ro/pls/proiecte/upl_pck2015.proiect?cam=2&idp=22358 (accessed on 21 November 2025). The first chamber notified is the Senate, which sent the legislative proposal to the Chamber of Deputies. The project is currently at the Chamber of Deputies, in the “sent for report to the standing committees of the Chamber of Deputies” stage, which is also the decision-making chamber.

ASPECTS CONCERNING THE LEGISLATION ON ARTIFICIAL INTELLIGENCE IN THE EUROPEAN UNION

Ph.D. Radu IOSOF

*"Dimitrie Cantemir" University of Târgu Mureș, Faculty of Law, Romania
Corresponding author: Radu Iosof*

Abstract

As Artificial Intelligence (AI) systems become increasingly complex and sophisticated, the need for a coherent legal framework grows ever more pressing. Within the European Union (EU), the regulation of Artificial Intelligence aims to ensure that technological innovation remains aligned with fundamental rights, ethical standards, and democratic values. This paper explores the key aspects of the legislative framework governing Artificial Intelligence in the European Union, focusing on the objectives, principles, and potential impacts of the proposed Artificial Intelligence Regulation (AI Act). The study seeks to analyze the main legal instruments that regulate Artificial Intelligence within the EU, as well as the general Code of Good Practice applicable to this field. Furthermore, it examines the organization of the European Artificial Intelligence Office and the European Commission's broader strategy regarding AI legislation in the Union. Close cooperation between lawmakers, industry, academia, and civil society will be essential to successfully navigate this evolving regulatory landscape and to ensure that the Artificial Intelligence Regulation (AI Act) achieves its intended objectives — promoting ethical and trustworthy AI while maintaining competitiveness and fostering innovation across the European Union.

Keywords: European Union laws, artificial intelligence, AI Act, AI Code of Practice GP AI, digital platforms

Introduction

Artificial intelligence (AI) represents one of the most significant contemporary technological innovations, having a substantial impact on the functioning of modern society. From the automation of economic processes to the use of algorithms in administrative or judicial decision-making, AI directly influences the fundamental rights and freedoms of individuals. In this context, the European Union has adopted a proactive approach to the regulation of artificial intelligence, aiming to create a coherent, unified, and predictable legal framework.

The need to legislate AI is justified by the risks associated with its use, such as the lack of algorithmic transparency, automated discrimination, excessive surveillance, or the erosion of human autonomy. Consequently, the European Union has sought to strike a balance between promoting technological innovation and protecting fundamental rights, as enshrined in the primary law of the Union.

As artificial intelligence systems become increasingly complex and powerful, the need for a coherent legal framework becomes ever more urgent. Within the European Union (EU), the regulation of artificial intelligence aims to ensure that technological innovation is aligned with fundamental rights, ethical standards, and democratic values.

Principles and Guidelines

The regulation of artificial intelligence in the EU is based on a series of principles and legal norms enshrined in the Union's founding treaties. Thus, Article 2 of the Treaty on European Union (TEU) establishes the fundamental values of the Union, such as respect for human dignity, freedom, democracy, equality, and the rule of law — values that must also be respected in the context of the use of new technologies.

Likewise, the Charter of Fundamental Rights of the European Union, which has binding legal force pursuant to Article 6 TEU, constitutes a central normative reference in AI legislation. Relevant rights include:

Article 1 – Human dignity;

Article 7 – Respect for private and family life;

Article 8 – Protection of personal data;

Article 21 – Non-discrimination;

Article 47 – Right to an effective remedy and to a fair trial.

These provisions form the legal foundation for the European Union's legislative intervention in the field of artificial intelligence.

Evolution of the Legal Framework.

The European Union's first steps toward regulating AI were taken through non-binding ("soft law") instruments, such as:

- the European Commission Communication "*Artificial Intelligence for Europe*" [1];
- the White Paper on Artificial Intelligence [2].

These documents highlighted the need for uniform legislation and paved the way for the adoption of a binding legal act. In this context, on 21 April 2021, the European Commission presented the Proposal for a Regulation on artificial intelligence (the Artificial Intelligence Act – AI Act).

On 9 December 2023, the Commission welcomed the political agreement on the AI Act [3]. On 9 July 2024, the amended Regulation on the EuroHPC Joint Undertaking entered into force [4], enabling the establishment of AI factories. This development facilitates the use of dedicated AI supercomputers for training general-purpose AI (GPAI) models. On 13 March 2024, the European Parliament adopted Regulation (EU) 2024/1689 of 13 June 2024 [5], also known as the AI Act, which represents the world's first comprehensive regulatory framework governing artificial intelligence and establishes harmonised rules for the development, placing on the market, and use of AI systems in the European Union.

The purpose of the Regulation is to improve the functioning of the internal market by establishing a uniform legal framework, particularly for the development, placing on the market, putting into service, and use of artificial intelligence systems within the Union.

The Regulation entered into force on 1 August 2024, and its application follows a predefined timetable for the period 2025–2027, in accordance with Article 113. Some provisions are already fully applicable, while certain requirements for high-risk AI systems and other provisions will apply only after the end of a transitional period.

From 2 February 2025, Chapters I ("General provisions") and II ("Prohibited AI practices") of the AI Regulation apply.

From 2 August 2025, Chapter III, Section 4 (Notifying authorities and notified bodies), Chapter V (General-purpose AI models), Chapter VII (Governance), Chapter XII (Penalties),

and Article 78 (Confidentiality) apply, with the exception of Article 101 (Fines for providers of general-purpose AI models).

From 2 August 2026, the AI Regulation is expected to apply in full, except for Article 6(1) and the corresponding obligations, which concern classification rules for high-risk AI systems.

From 2 August 2027, Article 6(1) and the corresponding obligations will also apply.

Subsequently, by 2 August 2028 and every three years thereafter, the Commission should assess the impact and effectiveness of voluntary codes of conduct.

By 2 August 2029 and every four years thereafter, the Commission should evaluate and revise the Regulation in light of evolving technological realities and the technical expertise required for its effective implementation and report to the European Parliament and the Council.

Technological evolution and its implications across all spheres of society necessitate the amendment of several existing EU legal acts and the adoption of new ones. At the same time, national legislation must be harmonised with the AI Act, and institutions responsible for monitoring its implementation and enforcement must be established at both EU and national levels.

The AI Regulation establishes a comprehensive risk-based regulatory architecture for AI developers and operators concerning specific AI uses. It is part of a broader policy package supporting the development of trustworthy AI, which also includes the AI Continent Action Plan [6], the AI Innovation Package [7], and the launch of AI factories. Together, these measures ensure safety, fundamental rights, and human-centric AI while strengthening adoption, investment, and innovation across the EU.

Article 50 of the AI Regulation introduces transparency obligations for providers and deployers of generative AI systems, with the objective of enhancing the traceability and intelligibility of AI-generated or manipulated content, such as deepfakes. These obligations address risks of deception and manipulation, thereby safeguarding the integrity of the information ecosystem, and complement other rules, including those for high-risk AI systems and general-purpose AI models.

To support compliance with these transparency obligations, the AI Office initiated the drafting of a Code of Practice on transparency of AI-generated content. The Code is developed by independent experts appointed by the AI Office through an inclusive process involving eligible stakeholders. If approved by the Commission, the final Code will serve as a voluntary tool for providers and operators of generative AI systems to demonstrate compliance with Article 50 (2) and (4), concerning the marking and detection of AI-generated content and the labelling of deepfakes and certain AI-generated publications.

The first draft of the Code of Practice on marking and labelling AI-generated content was published on 10 July 2025, in line with the timeline for finalisation in June 2026 [8]. The draft includes three separate chapters: Transparency, Copyright, and Safety and Security.

The *Transparency and Copyright* chapters make available to all providers of general-purpose AI models a structured mechanism to demonstrate compliance with Article 53 of the AI Regulation. The *Safety and Security* chapters apply only to the limited number of providers of the most advanced models subject to systemic-risk obligations under Article 55 [9].

Following the approval of the Code, AI model providers who voluntarily sign it may demonstrate compliance with the AI Regulation by formally adhering to its provisions. This will reduce their administrative burden and provide greater legal certainty than proving compliance through alternative mechanisms. Providers of general-purpose AI models may sign the Code by completing the signatory form and submitting the signed form to EU-AIOFFICE-CODE-SIGNATURES@ec.europa.eu. By signing, a presumption of compliance with the Code

is established for those providers, with the burden resting on authorities or interested parties to demonstrate a breach of the Regulation or of the provisions of the Code.

The Commission will collect all comments on the first draft from participants and observers of the Code of Practice until 23 January 2026. The second draft will be prepared by mid-March 2026, and the Code is expected to be finalised by June 2026.

The rules on transparency of AI-generated content will become applicable on 2 August 2026.

Training of AI providers, developers, and operators is indispensable for the effective implementation of the AI Regulation. In this context, the Commission promotes the AI Pact in order to help stakeholders prepare for the application of the AI Act.

The Legal Framework Currently in Force

Regulation (EU) 2024/1689 of 13 June 2024. At present, the provisions of Chapter I of the AI Regulation are in force, referring to the definition of concepts and AI literacy. Thus, Article 4 states that *“providers and deployers of AI systems shall take measures to ensure, to the greatest extent possible, a sufficient level of AI literacy among their staff and other persons dealing with the operation and use of AI systems on their behalf, taking into account their technical knowledge, experience, education and training, and the context in which the AI systems are to be used, as well as considering the persons or groups of persons with regard to whom the AI systems are to be used.”*

Therefore, it is necessary for personnel to be trained by those who operate and use artificial intelligence, not only from a technical perspective but also with respect to compliance with legal requirements and European regulatory standards. According to point 56, *“AI literacy”* means the skills, knowledge, and understanding that enable providers, deployers, and affected persons, taking into account their respective rights and obligations under this Regulation, to deploy AI systems in an informed manner and to be aware of the opportunities and risks of AI, as well as the potential harm it may cause.

The AI Regulation introduces a uniform and coherent regulatory framework across all EU countries, based on a forward-looking definition of AI and a risk-based approach [10]. The AI Regulation addresses the risks associated with certain uses of AI by classifying them into four levels of risk and establishing corresponding rules.

Minimal risk: Most AI systems, such as spam filters and AI-based video games, are not subject to any obligations under the AI Regulation, although companies may voluntarily adopt additional codes of conduct.

Specific transparency risk: Systems such as chatbots must clearly inform users that they are interacting with a machine, and certain AI-generated content must be labelled as such.

High risk: High-risk AI systems, such as AI-based medical software or AI systems used for recruitment, must comply with stringent regulatory requirements — risk mitigation systems, high-quality datasets, clear information for users, human oversight, etc.

Unacceptable risk: For example, AI systems that enable “social scoring” by governments or companies are considered a clear threat to citizens’ fundamental rights and are therefore prohibited.

The EU aims to become a global standard-setter in safe artificial intelligence. By developing a regulatory framework based on human rights and fundamental values, the EU can deploy AI systems that benefit everyone. These benefits include better healthcare, safer and cleaner transport, and improved public services for citizens. AI fosters innovative products and services, particularly in the fields of energy, security, and healthcare, as well as increased productivity

and more efficient production for companies. Public administrations, in turn, may benefit from more cost-effective and environmentally sustainable services, notably in the transport, energy, and waste management sectors.

Starting from 2 February 2025, the provisions of **Chapter II** of the Regulation also apply. Pursuant to Article 5(1) of that chapter, AI systems that pose unacceptable risks to fundamental rights, the rule of law, and the values of the European Union are prohibited [11], as follows:

Manipulation and deceptive techniques: placing on the market, putting into service, or using AI systems that employ subliminal, manipulative, or deceptive techniques with the purpose or effect of significantly distorting human behavior, thereby impairing individuals' capacity to make informed decisions.

Exploitation of vulnerabilities: placing on the market, putting into service, or using AI systems that exploit the vulnerabilities of natural persons due to age, disability, or socio-economic conditions, with the purpose or effect of significantly distorting their behavior in a manner that causes or is likely to cause significant harm.

Social scoring: placing on the market, putting into service, or using AI systems for social scoring, namely, for the evaluation or classification of individuals, based on behavioral or personal attributes, leading to unfavorable treatment in contexts unrelated to those in which the data were collected or unjustified in relation to the individual's social behavior or its severity.

Assessment and prediction of criminal risk of individuals: placing on the market, putting into service, or using AI systems solely for profiling individuals to assess or predict the risk of criminal behavior.

Facial recognition databases: placing on the market, putting into service, or using AI systems that create or expand facial recognition databases by extracting facial images indiscriminately from the internet or from CCTV footage.

Emotion recognition in the workplace and education: placing on the market, putting into service, or using AI systems to infer emotions in workplace or educational settings is prohibited, except in cases objectively justified for medical or safety reasons.

Biometric categorization: placing on the market, putting into service, or using AI systems to categorize individuals based on biometric data in order to infer sensitive information, such as race, political opinions, religion, trade union membership, or sexual orientation, is restricted.

Real-time remote biometric identification by law enforcement: the use of real-time remote biometric identification systems in publicly accessible spaces by law enforcement authorities is subject to a general prohibition, with narrowly defined exceptions.

After 2 August 2025, the provisions of **Chapter III, Section 4** (Notifying authorities and notified bodies) apply. The Commission and the AI Office work in close institutional cooperation with national competent authorities, which supervise the implementation and enforcement of the AI Regulation at national level. The national competent authorities include:

Market surveillance authorities, which oversee and ensure compliance with the rules for AI systems, including prohibitions and requirements for high-risk AI.

Notifying authorities, which designate and supervise notified bodies — independent entities that carry out conformity assessments prior to placing systems on the market.

Each Member State was required to designate and empower national competent authorities by 2 August 2025. To date, Romania has not notified its national authority, which does not appear on the website <https://digital-strategy.ec.europa.eu/en/policies/ai-act-governance-and-enforcement>.

Chapter V (General-purpose AI models) also applies. According to Article 3(63) of the Regulation, a general-purpose AI model (GPAI) is defined as an AI model, including one trained

on large amounts of data using large-scale self-supervision, that displays significant generality and is capable of competently performing a wide range of distinct tasks, regardless of how it is placed on the market, and that can be integrated into a variety of downstream systems or applications, excluding AI models used for research, development, or prototyping activities prior to being placed on the market.

From the wording of the chapter, it is understood that GPAI models are classified into two categories: general-purpose models as such and those presenting systemic risk. This classification depends on the magnitude and nature of the risk posed by the model.

According to Article 51 of the Regulation, a general-purpose AI model is classified as a GPAI model with systemic risk if it meets any of the following conditions:

a) It has high-impact capabilities evaluated on the basis of appropriate technical tools and methodologies, including indicators and benchmarks. According to Article 51(2), a GPAI model is considered to have high-impact capabilities when the cumulative amount of computation used for its training, measured in floating-point operations, exceeds 10^{25} . In such cases, the provider must inform the European Commission.

b) Based on a Commission decision, ex officio or following a qualified alert from the scientific panel, it demonstrates capabilities or impacts functionally equivalent to those mentioned above, in accordance with the criteria set out in Annex XIII to the AI Act.

GPAI models may present systemic risks such as foreseeable and actual adverse effects related to major accidents, disruptions of critical sectors, and serious consequences for public health and safety; actual or reasonably foreseeable negative effects on democratic processes, public and economic security; and the dissemination of illegal, false, or discriminatory content.

The obligations of GPAI model providers differ depending on whether or not they are classified as presenting systemic risk. Providers of GPAI models with systemic risk are subject to the same obligations as GPAI providers, supplemented by an enhanced set of regulatory requirements with which they must comply [12].

The provisions of **Chapter VII (Governance)** are also currently applicable. The Regulation seeks to establish a multi-level governance framework that, on the one hand, enables coordination and support for national-level implementation and, on the other hand, strengthens capacities at Union level and integrates stakeholders in the AI field.

EU Member States are required to designate or establish national notifying authorities responsible for setting up and carrying out the procedures necessary for the assessment, designation, and notification of conformity assessment bodies (notified bodies), as well as for monitoring them. These notified bodies play a central institutional role in the conformity assessment procedure for high-risk AI systems.

In addition to the notifying authority, other national authorities with responsibilities related to the protection of fundamental rights in the context of AI technologies are also recognized. For Romania, these authorities are listed on the European Commission's website separately from the notifying authorities to be appointed nationally under the Regulation: the Ombudsman, the National Audiovisual Council, the Permanent Electoral Authority, the National Supervisory Authority for Personal Data Processing, the Labour Inspectorate, the National Authority for the Protection of Children's Rights and Adoption, the National Council for Combating Discrimination, the National Agency for Equal Opportunities for Women and Men, and the Consumer Protection Authority [13].

Chapter XII (Penalties) and Article 78 (Confidentiality) also apply from 2 August 2025, with the exception of Article 101 (Fines for providers of general-purpose AI models).

Code of Practice. The AI Regulation refers in Article 56 to the development of Codes of Practice. Through an implementing act, the Commission may approve a Code of Practice and grant it general validity across the Union.

The first draft of this Code, published on 10 July 2025, addresses core regulatory areas such as transparency, copyright rules, and risk management. Providers of general-purpose AI models operating in the EU, companies, civil society representatives, rights holders, and academic experts are invited to submit their views and findings. The Commission will systematically integrate these contributions, when drafting the future Code of Practice for providers of general-purpose AI models.

This Code constitutes a compliance instrument that companies and AI firms can use to demonstrate adherence to the AI Act. Providers who sign and comply with the Code will benefit from reduced administrative burden and increased legal certainty.

Providers of the most advanced or impactful models presenting systemic risks — those exceeding 10^{25} FLOPs — will be required to meet supplementary compliance obligations, such as notifying the Commission and ensuring the safety and security of the model.

The Code is divided into three distinct chapters — Transparency, Copyright, and Safety & Security — and, as previously noted [14], this is not an arbitrary division but a deliberate regulatory choice reflecting *“an explicit recognition that the challenges of algorithmic governance require differentiated conceptual and methodological tools to address operational responsibilities, compliance with intellectual property regimes, and the management of emerging systemic risks.”*

Consequently, the Code will combine technical, mathematical, economic, philosophical, and legal concepts, thereby underscoring the interdisciplinary nature of AI regulation. This is natural, given that artificial intelligence has permeated all layers of society — from a simple smartphone to complex medical procedures or satellites. This interdisciplinarity also entails complex liability regimes for AI developers, providers, operators, and end users.

Initiated by the European Commission, the Code of Practice aims to provide normative guidance and operational benchmarks to ensure responsible and transparent use of AI.

GPAI providers, as well as civil society organizations, academics, and experts, may participate in one of the working groups of the virtual plenary sessions organized by the AI Office for its development. The launch plenary session took place last September, followed by two online meetings that resulted in the first two drafts of the Code.

This new version, based on comments received on the second version published on 19 December, presents more detailed measures for implementing each commitment. Two key commitments concern transparency and copyright. These apply to all general-purpose AI models, with a narrowly tailored exemption from transparency obligations for open-source models. While the Code maintains the principles established in the previous version regarding copyright, making them more readable, the tone is comparatively less prescriptive. The complaint-handling measure allows signatories to refuse to act on a complaint *“when rights holders’ complaints are manifestly unfounded or excessive, particularly due to their repetitive nature”* [15].

The AI Pact. To facilitate the transition to the new regulatory framework, the Commission launched the AI Pact, a voluntary initiative aimed at supporting future implementation, collaborating with stakeholders, and inviting AI providers and deployers from Europe and beyond to comply in a timely manner with the main obligations set out in the AI Regulation. In parallel, the AI Act Helpdesk also provides information and support for the smooth and effective implementation of the AI Regulation across the EU.

Institutions Responsible for the Implementation and Enforcement of the AI Act

To ensure proper enforcement, the AI Regulation establishes a number of governance bodies:

- *an AI Office within the European Commission*, responsible for ensuring compliance with common rules across the EU;
- *a scientific panel of independent experts* to support enforcement activities;
- *an AI Board*, composed of representatives of the Member States, to advise and assist the Commission and the Member States on the consistent and effective application of the AI Regulation;
- *an Advisory Forum*, enabling stakeholders to provide technical expertise to the AI Board and the Commission.

On 24 January 2024, through Decision C/2024/1459, the European Commission established the *European Artificial Intelligence Office*, as part of the administrative structure of the Directorate-General for Communications Networks, Content and Technology (DG CONNECT) [16]. Its mandate is to oversee the use of general-purpose artificial intelligence models and systems (GPAI).

The AI Office aims to enable the future development, deployment, and use of AI in a manner that fosters societal and economic benefits and innovation, while mitigating risks. The Office will play a key role in the implementation of the AI Act, particularly with regard to general-purpose AI models. It will also strive to promote research and innovation in trustworthy AI and to position the EU as a leader in international discussions.

The organizational structure of the European AI Office consists of six units and two advisers, reflecting the functional complexity of its mandate [17]. These include:

- *The “AI and Robotics Excellence” Unit*, which supports and funds research and development to promote an ecosystem of excellence. It coordinates the GenAI4EU initiative, stimulating the development of models and their integration into innovative applications;
- *The “Regulation and Compliance” Unit*, which coordinates the regulatory approach to facilitate the uniform application and enforcement of the AI Act across the Union, in close cooperation with the Member States. The Unit contributes to the investigation of potential infringements and manages sanctions;
- *The “AI Safety” Unit*, focused on identifying systemic risks posed by highly capable general-purpose models, potential mitigation measures, as well as evaluation and testing approaches;
- *The “AI Innovation and Policy Coordination” Unit*, which oversees the implementation of the EU AI strategy, monitors trends and investments, promotes AI adoption through a network of European Digital Innovation Hubs and the establishment of AI factories, and fosters an innovative ecosystem by supporting regulatory sandboxes and real-world testing;
- *The “AI for Societal Good” Unit and the “AI for Health and Life Sciences” Unit*, responsible for designing and implementing the AI Office’s international engagement on AI for good, such as weather modelling, cancer diagnosis, and digital twins for reconstruction;
- *Chief Scientific Adviser*;
- *International Affairs Adviser*.

The AI Office will employ more than 140 staff members to fulfil its tasks. The personnel will include technology specialists, administrative staff, lawyers, policy experts, and economists.

Their role will be to ensure the coherent implementation of the AI Act. The Commission will also achieve this by supporting governance bodies in the Member States. The AI Office will directly ensure compliance for general-purpose AI models. In cooperation with AI developers, the scientific community, and other stakeholders, the AI Office will coordinate the development of codes of practice, conduct testing and evaluation of GPAI models, request information, and impose sanctions where necessary.

Conclusions

The regulation of artificial intelligence in the European Union represents a complex and innovative legal endeavour aimed at addressing the challenges generated by the rapid development of digital technologies. Through the AI Act, the European Union strengthens its role as a global leader in AI regulation, promoting a human-centred approach based on respect for fundamental rights and the responsibility of the actors involved.

The effectiveness of this regulatory framework will depend on its consistent and uniform application across the Member States and on the European legislator's ability to adapt regulations to future technological developments.

Close cooperation between legislators, industry, the academic community, and civil society will be essential to successfully navigate this new regulatory landscape and to ensure that the Artificial Intelligence Act (AI Act) achieves its objectives — promoting ethical and trustworthy artificial intelligence while maintaining competitiveness and innovation within the European Union.

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ARTIFICIAL INTELLIGENCE IN THE LEGAL SYSTEM: EDUCATING LAWYERS AND MODERNISING INSTITUTIONS IN THE ERA OF AUTOMATED PUBLIC DECISION-MAKING

Patryk KOŁODYŃSKI

*Collegium Nobilium Opoliense, Poland
Corresponding author: Patryk Kołodyński*

Abstract

The rapid expansion of artificial intelligence has begun to reshape the foundations of contemporary legal systems. This article examines the reforms required in legal education and the modernisation of public institutions in response to the increasing use of algorithmic systems in administrative and judicial decision-making. Using a comparative approach based on developments in Poland, Romania, and leading international academic environments, the study identifies significant gaps in the preparation of future legal professionals, particularly in the areas of algorithmic oversight, technological risk assessment, model transparency, and the protection of individual rights. The analysis highlights shared challenges faced by both countries, including insufficient technological training, the absence of clear standards for explainability, and limited institutional mechanisms for supervising AI-driven processes. The article proposes a set of recommendations, including the integration of interdisciplinary modules into legal curricula, the development of technology-law clinics, and the adoption of systematic algorithmic audit procedures within public administration. The findings indicate that only the parallel transformation of legal education and institutional practice can safeguard democratic accountability, responsibility, and transparency in a reality increasingly influenced by data-driven and automated decision-making systems.

Keywords: Artificial intelligence, EU law, legal education, algorithmic decision-making, public governance

Introduction

Artificial intelligence has become a key element of modern public management. Public administration has long relied on statistical tools, forms, and IT systems, but the widespread adoption of machine learning models is introducing a qualitative change [1]. These systems not only support officials but also increasingly influence how problems are defined, how cases are classified, and which information is considered relevant in the decision-making process.

In many European countries, including Poland and Romania, AI-based tools are already being used in areas such as tax verification, social benefits, document analysis, and preliminary risk profiling systems [2], [3]. Formally, the decision is still made by a human, but the practical power of influence shifts to an earlier stage – to an algorithm that filters information, suggests a categorization of the case, or defines the "expected" scope of the decision [3].

From a legal perspective, this creates several tensions. Traditionally, public authority is exercised by identifiable entities – officials, judges, and functionaries – who are responsible for ensuring compliance with the law [5]. The introduction of complex algorithmic systems blurs this structure: a decision still takes the form of an official act, but its substantive justification may largely derive from an opaque computational process [6], [7]. If this process cannot be recreated and explained, the possibility of effective judicial review and the right to an effective remedy is called into question [8], [9].

This article begins with the premise that the legal system's response to these challenges must encompass two interconnected areas. First, legal education: future lawyers need a basic technological competence to understand how AI systems operate, their limitations, and how they may violate procedural safeguards [11], [12]. Second, the modernization of public institutions: administrative bodies and courts require new procedures, documentation standards, and oversight tools that will allow them to maintain control over automated processes in accordance with European legal frameworks such as the General Data Protection Regulation (GDPR) and the Artificial Intelligence Act [13].

The analysis focuses on Poland and Romania, two Central and Eastern European countries that – despite different paths to administrative modernization – face similar challenges: the pressure of digitalization, a skills gap among lawyers, and underdeveloped mechanisms for controlling algorithmic systems [14], [15].

Research Methodology

The study is qualitative, comparative, and interdisciplinary in nature. Four complementary methodological approaches were employed.

First, a desk research analysis of selected European Union legislation and soft law documents related to artificial intelligence was conducted, in particular: the Artificial Intelligence Act, the General Data Protection Regulation, and guidelines from international organizations [13], [16]- [18]. This analysis allowed us to determine the minimum requirements for transparency, human oversight, and documentation of algorithmic systems used by the public sector. Second, a comparative analysis of available data on the use of AI in public administration in Poland and Romania was conducted. This analysis drew on scientific publications, government reports, digitalization strategies, and descriptions of implemented tools — including solutions for automated document verification, scoring systems, and digital service portals [2], [3], [19]. Third, we drew on literature from legal theory, technology ethics, and data governance, which explores issues of explainability, algorithmic bias, and the new form of "algorithmic public authority" [4], [20]- [23]. This perspective allows us to place specific administrative practices within the broader context of shifts in the understanding of state accountability. Fourth, we analyzed selected legal education programs in Poland, Romania, and selected centers in Western Europe and North America. The goal was to determine the extent to which contemporary legal studies incorporate issues of artificial intelligence, data management, digital evidence, and interdisciplinary approaches to law and technology [11].

The methods used allow, on the one hand, to capture the normative and institutional context and, on the other, to identify structural gaps in the professional training of lawyers and in the functioning of public authorities.

Participants

Although the article is not based on an empirical study with respondents, it clearly identifies three groups of actors whose competencies determine the legal system's ability to oversee algorithmic decisions.

Firstly, *law students and future lawyers*. Their substantive preparation and professional ethos will determine whether courts and administrative bodies will be able to effectively oversee AI systems. If graduates have never encountered the structure of an algorithm, the concept of training data, or the problem of bias, it is difficult to expect them to question a decision based largely on a statistical model in practice.

Secondly, *public institutions*. This category includes central and local government bodies, courts, prosecutors' offices, regulatory bodies, and specialized agencies. These institutions are increasingly using machine learning tools, but they do not always have appropriate documentation, audit, and risk assessment procedures in place (Kuner, 2013; OECD, 2022).

Thirdly, *practicing legal professionals*. Judges, prosecutors, attorneys, legal advisors, data protection officers, and compliance specialists deal with evidence derived from algorithmic systems, automated classifications, and documents partially generated by AI. Their ability to ask the right questions, demand explanations, and identify weaknesses in such tools determines whether individual rights are truly protected [8], [24].

These three groups can be considered the "human infrastructure" responsible for ensuring that the automation of public decisions remains within the bounds of the rule of law rather than eroding it.

Material and Method

The approach used in this article combines normative, institutional, and didactic analysis.

From the perspective of normative material, European Union regulations and guidelines from international organizations are crucial. The Artificial Intelligence Act [13] introduces specific requirements for high-risk systems, which generally include tools used in the provision of public services. Simultaneously, the OECD and the Council of Europe are formulating principles for the responsible use of AI in government, emphasizing the need for transparency and auditability [16], [18].

The institutional material includes descriptions of AI implementations in various national administrations – from the X-Road infrastructure in Estonia to anticipating abuses in social benefit systems in the Netherlands [3]. For Poland and Romania, the following are relevant: The development of e-government, systems for automatic application completeness checks, scoring tools, and extensive online service portals [2], [14].

From the perspective of legal theory and technology ethics, work on the explainability structure of machine learning models, the problem of "black boxes," and the intuitive appeal of machine explanations was used [15], [21]- [23]. Of particular importance here is the concept of the end of traditional law in the face of "smart" technologies [20] and the critique of trust in scoring systems [6], [7].

Finally, the teaching material includes law school curricula and practical initiatives such as law and technology clinics and digital evidence modules [11]. This analysis shows that while innovative forms of education are emerging in some centers, in Poland and Romania they remain the exception rather than the norm.

Results

Algorithmic Public Authority and the Problem of Explainability

Analysis of practices in Poland and Romania indicates that AI systems are gradually shifting from a role of simple technical support to one that truly contributes to shaping the content of public decisions [3], [4]. This primarily concerns areas such as:

- initial selection and classification of cases,
- assessment of the risk of fraud or irregularities,
- automatic verification of document completeness,
- analysis of large data sets in administrative proceedings.

Although formally the decision is still signed by an official, in practice they often rely on the system's recommendation, which they cannot fully understand or independently verify [8]; [24]. Machine learning models, especially those based on deep neural networks, are characterized by a high level of complexity and difficulty translating their logic into legal language [22]; [23]. This raises the risk that an institution will attribute legality and compliance to a decision, even though its material foundations are not fully identifiable.

The literature has described this phenomenon as a new form of "algorithmic public authority," in which the infrastructure of data and models becomes — alongside traditional rules — a significant source of shaping an individual's position vis-à-vis the state [20]; [21]. Without appropriate mechanisms of transparency, the right to access to justification, and the possibility of independent auditing, the protection of fundamental rights is gradually weakened [17]; [18].

Gaps in Legal Education

In both countries analysed, legal education is primarily based on classical exposition of legal dogmatics, supplemented with elements of methodology and the practice of applying law. However, this type of education model—well-established and necessary—practically lacks basic technological literacy, knowledge of the functioning of algorithms, or the analysis of digital evidence. As a result, law graduates:

- can analyze regulations and case law,
- but often have no idea how a rule-based model differs from a data-driven model,
- do not understand the concepts of training data, validation data, overfitting, or bias,
- are unable to assess whether the presented results of algorithmic analysis are reliable and whether they violate the principles of due process [12].

This competency gap directly impacts professional practice. A lawyer unfamiliar with the basics of scoring systems will have difficulty challenging the decision of an authority relying on the results of such a system. A judge, on the other hand, lacking expert support or statistical assessment tools may unwittingly confer a presumption of correctness on the algorithm's results.

In **Poland** and **Romania**, while initiatives to introduce modules on the law of new technologies, personal data protection, or AI ethics are emerging, these are often elective and involve a small percentage of students [14]. Law and technology clinics, where students analyze specific cases related to the automation of public decisions, requests for access to information about algorithms, or challenging scoring in administrative proceedings, are rare.

Institutional Oversight Deficiencies

The third key finding of the analysis is the identification of systemic weaknesses within public institutions. Many authorities lack:

- uniform registers of AI systems used,
- transparent information about the purpose, provider, model type, and data categories,
- mandatory algorithmic impact assessments,
- internal procedures for suspending or correcting system operation in the event of doubts about its legality [17]; [25].

In practice, this means that algorithmic systems are often implemented "silently" – as part of IT projects, online service platform modernizations, or cost-optimization programs. This results in a phenomenon referred to in the literature as "silent automation" [6]; [7] citizens are unaware that their situation is co-determined by an algorithm, and courts only learn of this when the system fails spectacularly.

Administrative and common courts are particularly vulnerable, as they increasingly must assess evidence of a technical and algorithmic nature. Without access to independent experts, appropriate training and judicial practice regarding evidentiary standards for AI, there is a risk that courts will either be overly trusting of AI or, on the contrary, will automatically reject it without delving into the issue [15]; [22].

Conclusion

The analysis shows that artificial intelligence is not just another technical tool in public administration, but a phenomenon that impacts the very structure of public authority and the nature of the relationship between individuals and the state. In Poland and Romania, algorithmic systems are beginning to co-shape decisions in areas crucial to citizens' rights and obligations, but the pace of their implementation is outpacing the legal system's ability to ensure transparency, explainability, and accountability.

To preserve the substantive substance of the rule of law in the age of automation, a two-pronged reform is necessary.

First, the restructuring of legal education should aim to mainstream modules on artificial intelligence, data management, digital evidence, and technological risk analysis [11]. Lawyers do not need to become engineers, but they must understand the fundamentals of algorithms and be able to ask the right questions. Interdisciplinary law and technology clinics can play a special role.

Second, the modernization of public institutions requires the creation of transparent registers of AI systems, the introduction of mandatory algorithmic impact assessments in high-risk areas and ensuring courts and supervisory authorities have access to appropriate technical expertise [13]; [17]; [18]. Every decision in which AI has played a significant role should be accompanied by real — not merely declaratory — guarantees of an explanation and effective legal redress.

If these reforms are lacking, there is a danger that algorithmic systems will gradually take over decision-making functions, while remaining beyond the real reach of legal oversight. In an extreme scenario, the rule of law could be replaced by the rule of the model—a situation in which algorithmic parameters, rather than informed legal reasoning, determine the individual's situation [6]; [20].

However, if legal education and public institutions are appropriately modernized, artificial intelligence can become a tool that enhances the transparency, efficiency, and coherence of the

state apparatus. The condition is that law — not technology — determines the limits of algorithmic systems.

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PART II. PSYCHOLOGY SECTION

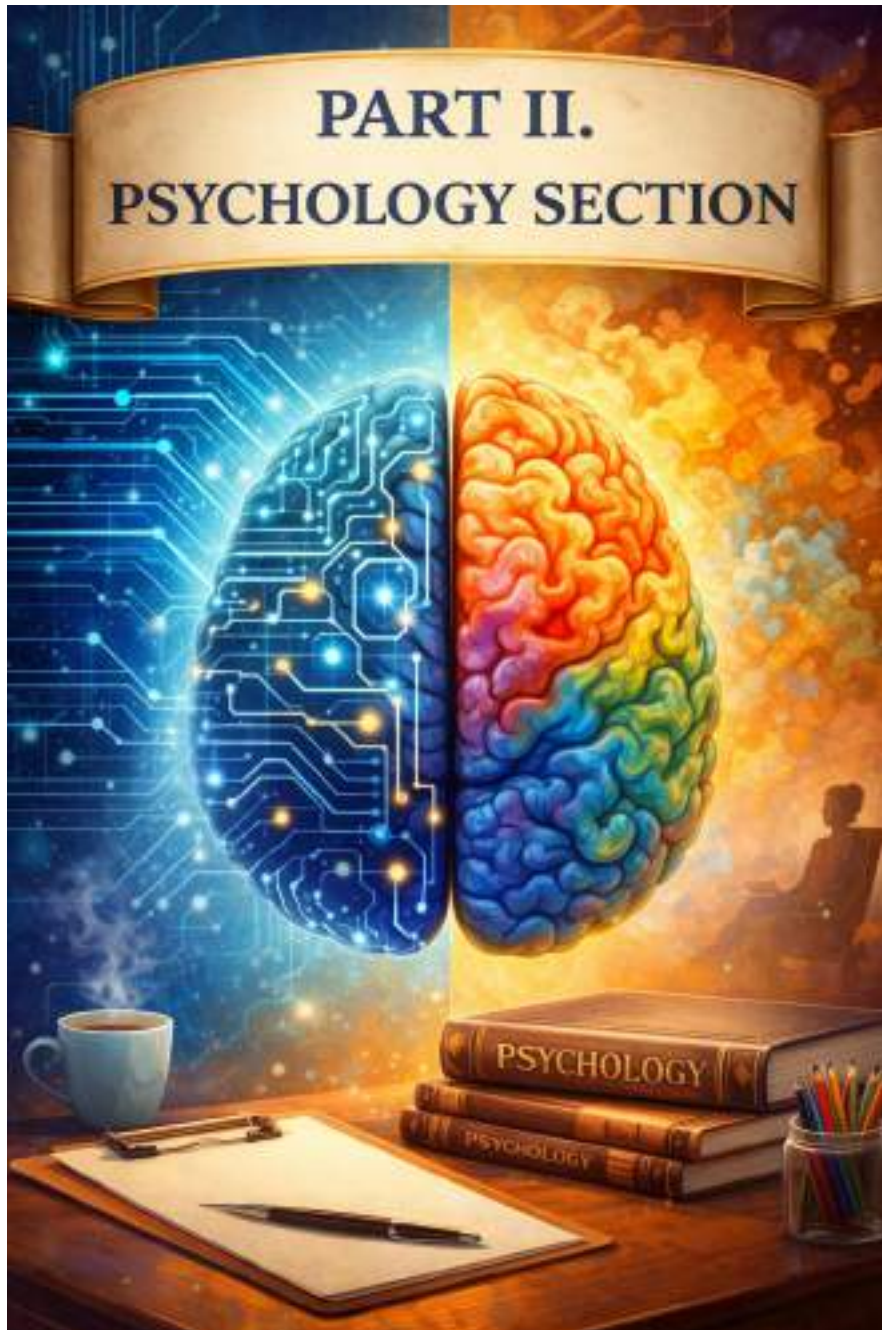


Figure P2. Psychology Section — Human Mind, Emotion, and Digital Cognition

This illustrative plate was created collaboratively by SS.M. Bălan and an AI-assisted design system to symbolize the intersection between cognitive processes, emotional dynamics, and contemporary psychological inquiry.

TYPES OF DIGITAL OFFENCES AND PSYCHOLOGICAL IMPLICATIONS. A FORENSIC-PSYCHOLOGICAL PERSPECTIVE ON EMERGING ONLINE AGGRESSIONS

Assoc. Prof. Sorina-Mihaela BĂLAN Ph.D.¹; Prof. Camelia STANCIU Ph.D.¹; Thais STANCIU²; Liliana BĂLAN²

¹“Dimitrie Cantemir” University of Târgu Mureș, Faculty of Psychology, Târgu Mureș, Romania;

²“George Emil Palade” University of Medicine, Pharmacy, Science, and Technology of Târgu Mureș, Faculty of Sciences and Letters Student

Corresponding author: Sorina-Mihaela BĂLAN: bsorinamihaela@yahoo.com

Abstract

The exponential expansion of digital technologies has profoundly altered the landscape of interpersonal interactions, giving rise to new forms of deviance and aggression. Cyberbullying, sextortion, grooming, and online radicalisation have emerged as hybrid offences that transcend the traditional boundaries between psychological trauma and criminal liability. The contemporary digital environment has profoundly reshaped communication patterns, social interaction, and psychological vulnerability, especially among young adults. While digital platforms facilitate connection and self-expression, they also generate contexts conducive to online aggression and deviant behaviours with significant psychological impact. This interdisciplinary study investigates university students' perceptions, experiences, and levels of awareness regarding digital offences such as cyberbullying, sextortion, online grooming, and digital radicalisation. The empirical research is based on a questionnaire designed and implemented by students from the fields of Communication and Emerging Media and Romanian and English Language Studies, emphasizing applied academic collaboration and communication competence. The respondents were students enrolled in Psychology programs, whose academic background allowed for a reflective and psychologically informed evaluation of digital aggression phenomena. The findings reveal moderate levels of awareness, a high perceived emotional and psychological impact of online aggression, and a strong demand for preventive strategies combining education, ethical communication, psychological support, and legislative measures. The results highlight communication as both a risk vector and a protective mechanism in digital environments. The study supports the integration of digital communication ethics, cyberpsychology, and media literacy into university curricula and underscores the value of student-led interdisciplinary research in addressing complex societal challenges.

Keywords: digital offences, cyberpsychology, online communication, interdisciplinary research, media literacy, student-led research

Introduction

The digital revolution has radically reshaped the sociocultural architecture of human interaction. With over 5 billion active internet users globally [1], the boundaries between private

and public spheres have become porous, facilitating both connection and exposure to new forms of psychological harm. Adolescents and young adults - who represent the demographic with the highest online engagement - are simultaneously the most technologically skilled and the most emotionally vulnerable [2].

Emerging digital aggressions such as *cyberbullying*, *online grooming*, *sextortion*, and *digital radicalisation* illustrate the convergence of psychology, technology, and criminology. Each involves a specific form of power imbalance, a psychosocial mechanism of coercion, and an evolving set of forensic challenges [3]. In contrast to traditional violence, digital offences often leave no visible physical traces but instead inflict profound psychological and reputational harm.

Digital platforms amplify aggression through anonymity, instantaneous dissemination, and the permanence of digital traces [4]; [5]. In forensic terms, these features complicate evidence collection and causal attribution, particularly when psychological consequences such as trauma, shame, or suicidal ideation emerge over time [6]. The forensic psychologist's role thus extends beyond diagnosis — it encompasses the reconstruction of intent, the assessment of credibility, and the analysis of digital behaviour patterns.

2. Conceptual and Theoretical Framework. The Psychosocial Foundation of Digital Aggression

Bullying, traditionally defined as intentional, repetitive aggression involving an imbalance of power [7], has migrated into the virtual realm as **cyberbullying**—a persistent, asynchronous form of abuse occurring across social media, messaging apps, and online communities. Meta-analyses indicate that approximately one in five adolescents has experienced cybervictimisation [8]; [9], while 15% admit to perpetration [10].

According to Zhao et al. [11], moral disengagement functions as a critical psychological mechanism underlying both perpetration and passive bystanding. Adolescents justify online aggression by diffusing responsibility (“everyone does it”) or dehumanising victims through anonymity. The *Online Disinhibition Effect* [4] further exacerbates this dynamic by lowering empathy thresholds and increasing impulsivity.

Cognitive and Affective Vulnerability

The digital environment interacts with neurocognitive immaturity characteristic of adolescence. Changes in executive functioning, emotional regulation, and dopaminergic sensitivity predispose youth to risk-taking and social validation behaviours [12]. This neurodevelopmental window explains why adolescents are disproportionately represented in cyberbullying, sextortion, and digital dependency cases [13].

From a cognitive-behavioural perspective [14], maladaptive interpretations of online rejection (“I am worthless”) can activate depressive schemas that escalate to suicidal ideation. The phenomenon of *bullycide* - suicide linked to bullying or cyberbullying - reflects this mechanism of psychological exhaustion and perceived entrapment [15].

3. Typology of Digital Offences

Digital offences with psychological components form a continuum ranging from covert manipulation to overt extortion. Forensic classification requires an interdisciplinary understanding of technology, motivation, and psychological harm.

Cyberbullying

Cyberbullying entails intentional, repetitive aggression conducted through digital channels, including social networks, instant messaging, or email [16]. Victims frequently experience *anxiety, social withdrawal, low self-esteem, and suicidal thoughts*. Systematic reviews confirm a strong association between *cybervictimisation* and *self-harm* [17]; [18].

In **Europe**, prevention frameworks emphasise *school-based resilience programmes and family mediation* [19]. In **Romania**, however, these interventions remain sporadic and underfunded, with limited integration into national curricula [20]. The contrast with **North American** and **Scandinavian** systems - where digital literacy is institutionalised - highlights the need for educational reforms anchored in psychological evidence.

Sextortion

Sextortion combines psychological coercion and financial exploitation, typically involving the threat of public exposure of intimate material.

Recent FBI reports [21] document *over 3,000 adolescent victims annually*, with several suicides linked to shame and public humiliation. From a forensic perspective, sextortion constitutes both a *crime of manipulation and a trauma of identity dissolution* - the victim's sense of agency is eroded through digital blackmail [22]. The case of Amanda Todd from **Canada** (2012) remains emblematic. After years of online exploitation, she recorded a video narrating her suffering before taking her own life. Her death prompted international legal and educational reforms addressing online sexual coercion.

Grooming

Online grooming refers to the gradual manipulation of minors by adults to gain trust for subsequent exploitation. It unfolds through three stages: emotional bonding, desensitisation, and control [23]; [24]. Victims often exhibit symptoms consistent with post-traumatic stress disorder, depression, and self-blame.

European comparative studies [25] reveal that grooming incidents are more prevalent in countries with limited digital surveillance infrastructure and low parental mediation. Artificial intelligence systems capable of detecting semantic grooming patterns could serve as preventive tools, yet their deployment raises ethical and privacy concerns [26].

Digital Radicalisation

Digital radicalisation involves cognitive and emotional alignment with extremist ideologies through sustained exposure to online propaganda [27]. Algorithms that promote engagement inadvertently amplify radical narratives, creating echo chambers where aggression becomes normalised.

Forensic evaluation must consider both ideological indoctrination and psychosocial vulnerability. Many adolescents drawn to radical movements report histories of social isolation and identity crises, making digital communities' attractive sources of belonging [28]. The

medico-legal challenge lies in distinguishing ideological persuasion from psychological manipulation — a boundary blurred by algorithmic reinforcement.

Other Emerging Offences

- *Deepfake victimisation*, involving synthetic media used to impersonate or humiliate individuals, represents a new frontier of psychological harm.
- *Digital voyeurism and revenge pornography* extend the boundaries of consent violations, causing lasting reputational damage.
- *Cyberstalking*, characterised by persistent monitoring and intrusion, induces chronic anxiety and hypervigilance akin to trauma reactions.

These emerging forms of digital deviance illustrate the dynamic evolution of the forensic–psychological field, necessitating adaptive legal and therapeutic frameworks.

4. Psychological Implications of Digital Offences

Emotional Trauma and Psychopathological Correlates

Digital victimisation induces psychological consequences comparable in intensity to those of face-to-face violence, yet often more persistent due to the inescapable nature of online exposure. Victims of cyberbullying, sextortion, and grooming frequently develop *depression, anxiety disorders, sleep disturbances, and suicidal ideation* [17]; [15].

Meta-analytic evidence demonstrates that *victims of cyberbullying exhibit double the risk of suicide attempts* compared to non-victims [8]. The concept of *bullycide* - suicide following prolonged online harassment - illustrates the extreme endpoint of psychological exhaustion and perceived entrapment.

Psycho-dynamically, the aggression experienced in digital contexts activates early attachment vulnerabilities and identity fragmentation [29]. *Shame* and *humiliation* - publicly witnessed online - produce *narcissistic injury*, often accompanied by *self-blame* and *learned helplessness*. Adolescents exposed to sexual blackmail or grooming also exhibit *post-traumatic stress symptoms* and avoidance behaviours [23].

Cognitive–Behavioural Mechanisms

Cognitive theories [14] highlight the mediating role of negative automatic thoughts (“I am powerless”, “I will be humiliated forever”). These beliefs sustain the emotional dysregulation observed in cyber-victims. Repeated exposure to hostile online feedback fosters *catastrophic thinking* and a distorted perception of social reality.

At the neural level, recent fMRI studies demonstrate *altered functional connectivity in adolescents with internet-related trauma*, particularly in regions associated with emotion regulation and reward processing [30]. This neuropsychological vulnerability explains why digital victimisation can exacerbate impulsivity and addictive behaviours.

The Family and Educational Context

The family system functions as both a buffer and a risk amplifier. Meta-analyses show that *warm parenting and open communication reduce cybervictimisation*, while overcontrol or neglect increase it [19]. Parental mediation strategies, such as co-viewing and active discussion of online risks, mitigate exposure to harmful digital environments [31].

Educational institutions in **Europe** increasingly integrate *digital citizenship curricula and psychoeducational prevention programmes* [18].

In **Romania**, initiatives remain fragmented, often limited to reactive measures after incidents occur. To bridge this gap, schools must embed *psychological resilience training and early detection protocols* supported by school counsellors and forensic psychologists.

5. Forensic–Psychological Dimensions

From a *medico-legal* standpoint, digital offences require the adaptation of classical forensic methods. Psychological autopsies in cases of suicide associated with cyberbullying or sextortion must consider *indirect causation*, also known as *induced suicide* [32].

The forensic assessment thus examines the *psychological* sequence between digital aggression and suicidal behaviour, integrating witness statements, online *communication* logs, and behavioural traces.

The *chain of digital evidence* poses unique challenges. Screenshots, chat archives, and metadata must be collected under conditions that preserve authenticity and continuity. Forensic psychologists play a crucial role in interpreting digital communications to assess intent, coercion, or cognitive manipulation [6].

6. Psycho-Educational Interventions

Digital Hygiene and Emotional Literacy

The concept of digital hygiene extends beyond technological awareness to include emotional self-regulation, empathy, and critical media literacy [5]. Preventive education should empower adolescents to recognise manipulation strategies, maintain digital boundaries, and report inappropriate content.

School-based programmes combining Cognitive - Behavioural Therapy (CBT) techniques with *peer mentoring* have shown effectiveness in reducing cyberbullying by up to 25% [33]. Moreover, interventions addressing empathy and bystander behaviour - core components of the KiVa model in **Finland** - have proven transferable to other European contexts [25].

Integrating Forensic Expertise in Education

A promising innovation involves forensic-informed education, whereby psychologists and legal professionals collaborate to deliver workshops on online consent, evidence preservation, and digital citizenship. This approach enhances both legal literacy and psychological resilience among adolescents.

University-level curricula, particularly in psychology and law faculties, should integrate courses on *digital ethics, forensic assessment, and cyberpsychology*, equipping future professionals to navigate emerging ethical dilemmas.

Psychotherapeutic Support for Victims

Therapeutic intervention follows a multi-modal model:

- *Cognitive restructuring* to challenge guilt and shame;
- *Trauma-focused CBT* or *EMDR* for reprocessing intrusive memories;
- *Psychoeducation* for families to rebuild trust and communication.

Research confirms that early psychotherapeutic engagement significantly reduces chronic trauma symptoms and suicide risk among cybervictims [18]; [17].

Future Directions and Global Comparisons

Cross-continental comparisons reveal striking disparities in policy and prevention:

- In **Northern Europe**, integrated school–family–state frameworks ensure early detection of digital aggression;
- In **North America**, legislation such as *Megan Meier’s Law* directly criminalises cyber-harassment leading to suicide;
- In **Asia**, rapid digitalisation has outpaced psychological infrastructure, resulting in higher prevalence of internet addiction and cybercrime [30].
- **Romania and Eastern Europe** occupy an intermediate position, where technological access is high but *preventive education and psychological services remain underdeveloped*. The future lies in building interdisciplinary teams — combining psychology, forensic medicine, IT security, and pedagogy — to monitor and intervene across digital environments.

The integration of *AI-assisted forensic analysis* represents another frontier.

Machine learning can detect semantic indicators of grooming or suicidal ideation, but ethical governance must ensure data privacy and avoid algorithmic bias [26].

Study of the Perceptions of Digital Offences and Online Aggression among Psychology Students

Digital Communication and Psychological Vulnerability - An Interdisciplinary Perspective

In contemporary society, *digital communication* has become one of the primary modes of social interaction, deeply influencing cognitive, emotional, and relational processes.

From a *psychological* perspective, online environments represent spaces of opportunity but also of heightened vulnerability, where identity construction, self-esteem, and emotional safety may be significantly affected by mediated messages.

Online aggression is not merely a technological issue but a form of dysfunctional communication, expressed through hostile language, repetitive messaging, public exposure, emotional manipulation, or strategic silence. Phenomena such as *cyberbullying*, *sextortion*, and *grooming* operate through discursive and symbolic mechanisms that exert profound psychological effects, including *anxiety*, *emotional distress*, *loss of control*, and *social withdrawal*.

An **interdisciplinary** approach is therefore essential. The present study integrates: **Psychology**, through the academic profile of the respondents and the analysis of emotional and cognitive impact; **Communication and Emerging Media** Studies, through the conceptualisation of digital environments and message circulation; **Linguistic** Studies, through attention to language use, meaning construction, and interpretive processes in online contexts.

Methodology

An Interdisciplinary Questionnaire Applied to Psychology Students

The research instrument was designed and implemented by students from **Romanian and English Language Studies**, and **Communication and Emerging Media**, under academic supervision. This approach reflects a model of learning through research and participatory academic practice.

The respondents were exclusively students enrolled in *Psychology programs*, which enhances the interpretative relevance of the findings, as participants possess foundational knowledge of emotional, behavioural, and social mechanisms involved in online aggression.

The questionnaire addressed:

- levels of awareness regarding digital offences;
- direct and indirect experiences with online aggression;
- perceptions of psychological impact associated with harmful digital communication;
- the role of education,
- ethical communication, and
- artificial intelligence in prevention strategies.

Sample Characteristics

The sample consists of 95 undergraduate students enrolled in *Psychology* programs, aged between 19 and 50 years. Gender distribution indicates a predominance of female participants, with 76 female students (80%) and 19 male students (20%).

This distribution reflects the demographic structure commonly observed in psychology-related academic programs and provides an adequate basis for exploring perceptions related to digital offences within this population.

Results

Daily Online Exposure.

Regarding the average amount of time spent online per day, the data indicate substantial digital engagement among respondents. Specifically, 42% of students reported spending between 2 and 4 hours daily online, while 27% indicated an exposure of 4 to 6 hours per day. A smaller proportion, 22%, reported spending less than 2 hours online, whereas 9% stated that they spend more than 6 hours per day in digital environments.

These results highlight the central role of online communication and digital platforms in students' daily routines, underscoring the relevance of examining digital risks within this group.

Awareness of Digital Offences.

Regarding students' self-reported level of awareness of digital offences such as cyberbullying, sextortion, and online grooming, the results indicate a predominantly moderate level of perceived knowledge.

Most respondents (52%) reported that they feel well informed about these phenomena. In contrast, 29% of the participants described themselves as slightly informed, suggesting partial or fragmented knowledge. A smaller proportion (14%) indicated that they are very well informed, while 5% of respondents reported being uninformed about digital offences.

These findings suggest that although more than half of the students perceive themselves as having an adequate level of awareness, a substantial proportion report limited or insufficient knowledge, highlighting potential gaps in formal or informal education regarding digital risks.

Perceived Harmfulness of Online Behaviours.

When asked to evaluate which online behaviours are most harmful for adolescents, most respondents (60%) indicated that cyberbullying, sextortion, grooming, and digital radicalisation have an equally harmful impact.

This response reflects a comprehensive perception of digital risk, recognizing the cumulative psychological and social consequences of multiple forms of online aggression. Among respondents who identified a specific behaviour as the most harmful, 23% considered cyberbullying behaviours—such as insults, exclusion, and humiliation—to be the most dangerous. 8% identified sextortion, defined as intimate-content blackmail, as the most harmful online behaviour affecting adolescents. Additionally, 3% of respondents selected grooming behaviours, involving adult manipulation of minors, and another 3% identified digital radicalisation, referring to exposure to extremist ideologies, as the most harmful.

These results indicate that while individual forms of online aggression are recognized as particularly damaging by some respondents, the dominant perception is that all analysed behaviours pose serious and comparable risks to adolescents' psychological well-being.

Experience with Online Aggression

Analysis of respondents' personal experience with online aggression reveals varying degrees of direct and indirect exposure. A substantial proportion (43%) reported that they have not personally been victims or witnesses of online aggression but know individuals who have experienced such situations, indicating indirect exposure through social networks. Additionally, 21% of respondents stated that they have neither been victims nor witnesses of online aggression. However, 20% reported having been witnesses to online aggression, while 16% indicated that they have been direct victims of such behaviour.

Overall, these findings demonstrate that a significant proportion of students (36%) have either witnessed or directly experienced online aggression, underscoring the prevalence of digital violence within the social environment of university students.

Perceived Role of Online Anonymity

With respect to the relationship between online anonymity and aggressive behaviour, the results reveal a strong perceived association. A substantial majority (77%) believe that online anonymity encourages aggressive behaviour, while 22% consider that anonymity contributes to aggression to some extent. Only 1% of respondents believe that there is a slight relationship between anonymity and aggressive conduct.

These results suggest a widespread perception of anonymity as a key risk factor in digital aggression.

Psychological Harm of Online Aggression

When comparing online aggression with face-to-face violence in terms of psychological harm, most respondents (71%) consider the two forms of aggression to be equally harmful. Furthermore, 19% perceive online aggression as more harmful than direct, face-to-face violence, while 10% believe it to be less harmful.

This distribution indicates a strong recognition of the psychological severity of digital aggression, often equated with or exceeding traditional forms of violence.

Preventive Measures Against Digital Offences

Respondents identified several preventive actions as effective against digital offences. The most frequently selected option was combined measures, including educational, psychological, and legislative approaches (57%). Other preventive strategies were also considered relevant: Stricter legislation and online monitoring – 30%§ Parental supervision and communication – 27%§ Psychological counselling and early intervention – 24%§ Digital

hygiene and media literacy education – 23%§ *These findings suggest a clear preference for integrated, multi-level prevention strategies.*

Role of Universities and Academic Training

Regarding the inclusion of topics such as cyberpsychology, digital ethics, and forensic psychology in university curricula, respondents expressed strong support. A majority (59%) consider such courses very important, 35% consider them important, and 6% view them as partially important.

This reflects a high level of acceptance for expanding academic training in response to emerging digital risks.

Confidence in Identifying Online Manipulation

In terms of self-perceived ability to identify signs of online manipulation (e.g., grooming or sextortion), 61% of respondents reported being confident, while 32% stated they are very confident. A smaller proportion (6%) indicated being less confident, and 1% reported being not confident at all.

Overall, the results suggest a relatively high level of perceived competence, though a minority still report uncertainty.

Artificial Intelligence in Preventing Digital Offences

When asked about the potential role of artificial intelligence (AI) in detecting and preventing digital offences, most respondents expressed cautious optimism. Specifically, 62% believe that AI could help if adequate ethical measures are in place, while 18% are fully confident in its preventive potential.

Conversely, 10% reported being unsure, and another 10% believe that AI would not help and might generate new risks.

Perceived Urgent Needs in Romania

Finally, respondents identified several urgent societal needs related to digital offences in **Romania**. The most frequently mentioned was education and awareness campaigns (66%), followed by updating legislation (46%). Additionally, 40% highlighted the need for accessible psychological support services for victims, preferably free of charge, while 30% emphasized the importance of closer collaboration between psychologists and forensic experts.

These results indicate a generally positive but ethically conditioned perception of AI-based solutions.

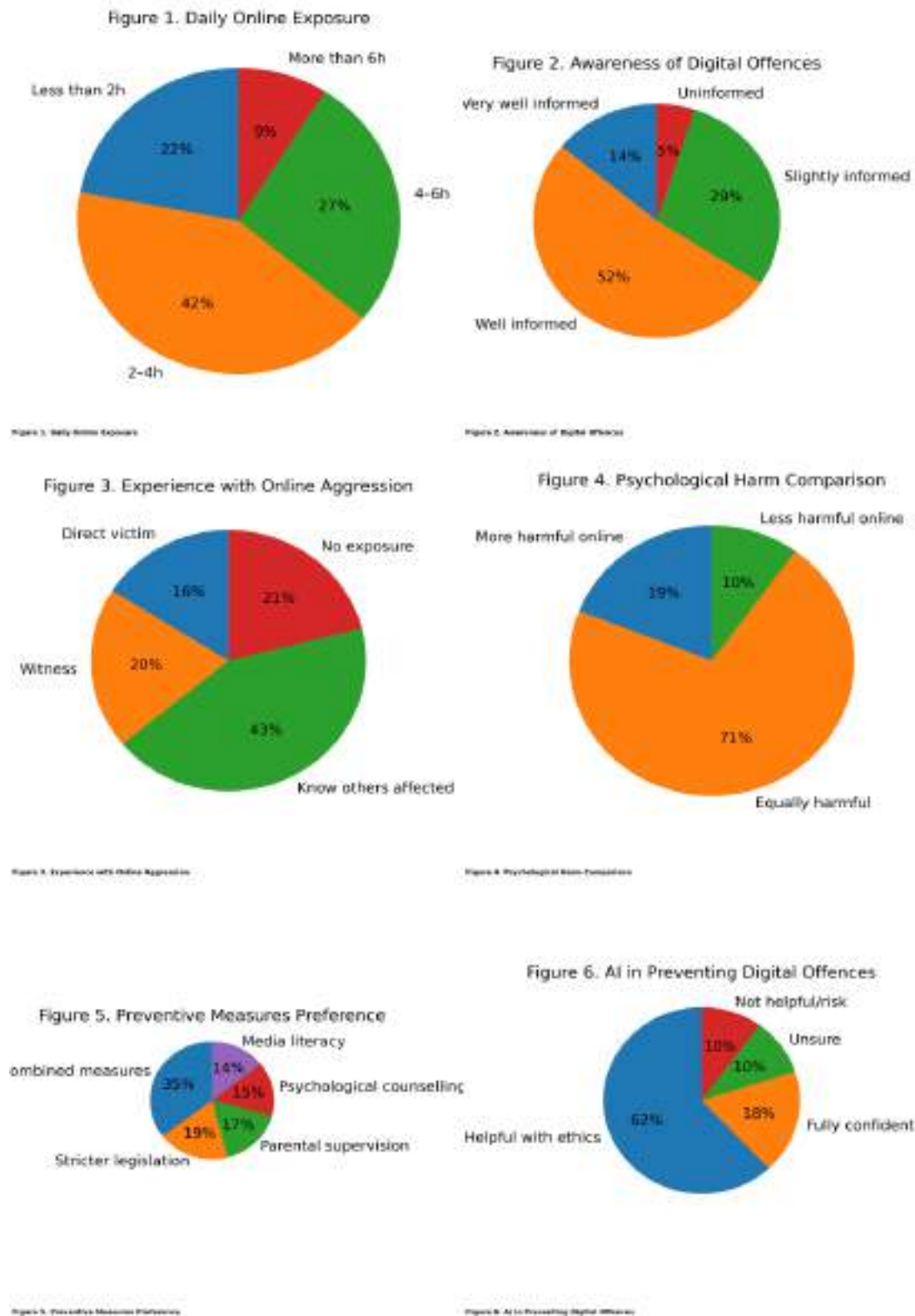


Figure 1-6 Composite representation of students' digital exposure, awareness, and prevention-related perceptions.

Figures 1–6. This composite figure presents a set of pie charts illustrating key dimensions of students' engagement with digital environments and online aggression, including daily online exposure, awareness of digital offences, personal and vicarious experience with online aggression, perceived psychological harm of online versus face-to-face violence, preferred preventive and intervention strategies, and attitudes toward the ethical application of artificial intelligence in the detection and prevention of digital offences.

Key Conclusions of the Study

The results of the present study indicate that psychology students are moderately informed about digital risks, including *cyberbullying, sextortion, grooming, and digital radicalisation*. Although a foundational level of awareness exists, the findings suggest that students' knowledge is uneven and may benefit from systematic academic and educational reinforcement.

Digital offences such as cyberbullying, sextortion, grooming, and digital radicalisation are perceived as equally harmful to adolescents as offline violence, highlighting the psychological severity attributed to online aggression. This perception reflects an increased recognition of the emotional and cognitive impact of mediated communication and digital victimisation.

Furthermore, the data show that approximately one third of students have either witnessed or directly experienced online aggression, indicating that digital violence represents a tangible and prevalent *phenomenon* within students' social environments rather than a distant or abstract risk.

Respondents clearly identified several urgent *societal needs in relation to digital offences*:

- the development of digital education and awareness campaigns.
- updating and strengthening legislation addressing online aggression.
- ensuring accessible psychological support services for victims.
- promoting interdisciplinary collaboration between psychology, communication, education, and forensic fields.

Additionally, the *inclusion of courses focused on digital psychology, cyberpsychology, and online ethics within university curricula is widely regarded as essential*. Artificial intelligence is viewed as a major opportunity for prevention and detection, but only under conditions of strict ethical regulation and safeguards.

Psychology and Communication in Digital Contexts

The findings reveal a moderate level of awareness regarding digital risks, accompanied by a strong perception of the psychological harm caused by online aggression.

Most respondents consider *digital violence* to be as harmful as face-to-face violence, supporting psychological theories related to message internalisation, emotional processing, and the long-term effects of symbolic aggression.

Online anonymity is perceived as a significant *factor* contributing to *communicational disinhibition*, facilitating aggressive behaviour while reducing social accountability. From a psychological perspective, this dynamic is closely associated with reduced empathy, deindividuation processes, and weakened self-regulation in digital environments.

These mechanisms highlight the importance of addressing not only technological factors but also communicational and psychological dimensions of online behaviour.

Conclusions

This study demonstrates that online aggression is a complex, *multidimensional phenomenon* situated at the intersection of *psychology* and *communication*. Digital language, imagery, and discursive strategies function not merely as channels of expression but as active agents capable of producing significant psychological harm, affecting emotional well-being, self-perception, and social adaptation among young adults.

The active involvement of students from *communication* and *linguistic* disciplines in designing and implementing the research instrument, alongside *psychology* students as respondents, illustrates the value of authentic interdisciplinarity in academic research. This collaborative approach enhances methodological relevance and reinforces the role of communication as both an analytical lens and a practical tool.

Communication thus emerges not only as an object of study but also as a key resource for prevention, education, and social responsibility. Integrating *cyberpsychology*, *ethical digital communication*, and *media literacy* into university curricula represents a strategic direction for reducing digital risks and fostering healthier online environments grounded in empathy, responsibility, and critical thinking.

Final Remarks

The present study contributes to the growing body of psychological research addressing digital aggression by offering an empirically grounded, interdisciplinary perspective on psychology students' perceptions of online offences.

The findings confirm that digital aggression is not perceived as a marginal or secondary phenomenon, but as a form of violence with psychological consequences comparable to those of face-to-face aggression.

Students' moderate level of awareness, combined with a high sensitivity to the emotional and psychological impact of online aggression, suggests that cognitive understanding of digital risks does not automatically translate into comprehensive preparedness or effective coping strategies. This gap underscores the necessity of structured academic interventions aimed at strengthening both knowledge and applied psychological competencies in digital contexts.

By highlighting the role of communication processes — such as anonymity, message repetition, and symbolic exposure — the study reinforces psychological models that conceptualise online aggression as a form of relational and emotional harm mediated through language and digital interaction. These insights support the need for psychological approaches that address not only individual vulnerability, but also the communicational environments in which aggression emerges and is maintained.

Strategies to Prevent Digital Aggressions in Education

From an applied psychological perspective, the results of this study have several important implications for educational practice, prevention strategies, and institutional policy.

The Figure 7. presents key interdisciplinary and AI-supported strategies for preventing digital aggression in higher education, integrating curriculum development, counselling and early intervention, psychoeducational prevention, ethically guided AI monitoring, and cooperation across psychology, communication, linguistics, and forensic sciences.

First, the findings support the systematic integration of cyberpsychology, digital ethics, and forensic psychology into university curricula, particularly within psychology programs. Such courses should focus not only on theoretical knowledge, but also on practical skills related to risk recognition, emotional regulation, intervention strategies, and ethical decision-making in digital environments.

Second, the high proportion of students who have witnessed or experienced online aggression highlights the need for accessible psychological support services within academic institutions. Universities should develop targeted counselling and early intervention programmes addressing digital victimisation, with particular attention to emotional trauma, anxiety, and social withdrawal associated with online aggression.

Third, the perceived role of anonymity in facilitating aggressive behaviour indicates the importance of preventive psychoeducational programmes that promote empathy, responsibility, and reflective communication. Training in digital communication competence and emotional awareness can contribute to reducing disinhibition and fostering healthier online interactions.

Fourth, the cautiously optimistic perception of artificial intelligence as a preventive tool suggests opportunities for integrating AI-assisted detection and monitoring systems within educational and clinical frameworks. However, such applications must be accompanied by strict ethical safeguards, transparency, and psychological oversight to prevent secondary harm or misuse.

Finally, the interdisciplinary nature of this research demonstrates the value of collaboration between psychology, communication, linguistics, education, and forensic sciences. Interdisciplinary cooperation enhances both the analytical depth and practical relevance of research on digital aggression, facilitating more effective prevention and intervention strategies.



Figure 7. Interdisciplinary and AI-Supported Strategies for Preventing Digital Aggression in Higher Education. Author: Liliana Bălan.

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SUBJECTIVE TIME PERCEPTION IN CLINICAL, DEVELOPMENTAL, AND THERAPEUTIC CONTEXTS. A TRANSDIAGNOSTIC, MIXED-METHODS, AND NEUROBIOLOGICAL RESEARCH PERSPECTIVE

Associate professor Sorina-Mihaela BĂLAN¹, Ph.D.; Professor Adrian-Cristian PAPARI, Ph.D.²

¹*Vicerector at Dimitrie Cantemir University from Târgu Mureș, Faculty of psychology*

²*Director of the UAS Research Center, Andrei Șaguna University Constanta, Romania*

Coresponding author: Sorina-Mihaela BĂLAN: bsorinamihaela@yahoo.com

Abstract

This study examines subjective time perception as a transdiagnostic and neurobiologically grounded dimension of mental functioning that integrates executive control, affective regulation, and autobiographical continuity. Drawing on classical psychiatric psychopathology and contemporary cognitive neuroscience, the paper synthesizes evidence from systematic reviews and meta-analyses published between 2015 and 2025 to investigate temporal distortions across affective syndromes, schizophrenia spectrum disorders, neurodevelopmental conditions (ADHD, ASD), stress-related states, addictive behaviours, chronic pain, and major neurocognitive disorders. A mixed-methods research framework is advanced, combining laboratory-based timing paradigms, ecological digital phenotyping, and phenomenological qualitative analysis to connect objective measures of temporal precision and accuracy with lived temporal experience and clinically relevant outcomes. Meta-analytic convergence indicates that depressive states are predominantly associated with alterations in the subjective passage of time, schizophrenia spectrum disorders with marked impairments in temporal precision and coordination, ADHD with medium-to-large timing deficits moderated by working memory and attentional control, autism spectrum disorder with vulnerabilities in complex temporal integration, and addiction- and stress-related conditions with pronounced distortions in future orientation and present salience. The findings confirm the study's central hypotheses and support a dimensional model in which disturbances of time processing, time experience, and time perspective reflect coordinated disruptions across distributed neural systems, including fronto-striatal dopaminergic circuits, hippocampal–prefrontal memory networks, and interoceptive salience pathways. Subjective time perception is thus positioned as a clinically actionable biomarker for diagnostic refinement, prognostic modeling, and personalized intervention strategies, advancing a translational perspective that integrates empirical rigor with phenomenological insight in contemporary mental health sciences.

Keywords: subjective time, time perception; transdiagnostic marker; depression; schizophrenia; ADHD; ASD; dementia; dopamine; neuroimaging; mixed-methods; computational psychiatry.

1. Introduction. Clinical and Scientific Framing of Subjective Time

Subjective time perception constitutes a core dimension of mental functioning through which individuals organize memory, emotion, and intentionality into a coherent narrative of self and world. Classical clinical psychopathology conceptualizes temporal experience as a structural organizer of affective regulation, volitional capacity, and personality integration, attributing it diagnostic and prognostic value across major psychiatric categories [1] [2].

From the standpoint of clinical psychology, lived time represents the experiential medium through which patients construct narratives of illness, recovery, and future possibility, rendering temporal orientation a critical component of therapeutic alliance and treatment adherence [3]. Distortions of subjective time — manifested as stagnation, acceleration, fragmentation, or disorientation — therefore transcend symptom status and emerge as transdiagnostic indicators of psychological vulnerability and neurocognitive integrity.

Contemporary cognitive neuroscience reinforces this integrative view by demonstrating that temporal experience arises from distributed neural systems involving executive control (dorsolateral prefrontal cortex), reward and motivation (basal ganglia, dopaminergic pathways), and episodic integration (hippocampal and medial temporal structures) [4] [5] [16] [19]. Meta-analytic evidence further confirms systematic alterations in temporal processing across depression, schizophrenia, ADHD, ASD, stress-related conditions, and neurocognitive disorders, supporting the conceptualization of time perception as an empirically grounded axis of psychopathology rather than a metaphorical descriptor [6] [15].

2. Aims, Research Questions, and Hypotheses

2.1 Aims

The present study pursues two interrelated objectives:

(A1) to synthesize high-level evidence on subjective and objective time distortions across major psychiatric and neurodevelopmental conditions, integrating classical clinical models with contemporary meta-analytic and neurobiological findings [1] [2] [6] [15];

(A2) to formulate a mixed-methods research framework capable of linking laboratory timing metrics, ecological behavioral rhythms, and lived temporal narratives into clinically actionable temporal phenotypes.

2.2 Research Questions

RQ1: Which psychiatric and neurodevelopmental conditions exhibit the most robust and replicable alterations in temporal precision, temporal accuracy, and lived time experience?

RQ2 Which moderators (e.g., working memory capacity, dopaminergic medication, symptom severity, task complexity, interval range) account for heterogeneity across empirical findings?

RQ3: How do objective timing impairments relate to phenomenological temporal narratives such as “frozen time,” “accelerated futurity,” or “fragmented present”?

RQ4: Can temporal metrics serve as prognostic indicators for functional outcome, relapse risk, and treatment adherence?

2.3 Hypotheses

H1 - Depressive symptom severity will predict slowed passage-of-time experience more strongly than objective duration estimation deficits, consistent with meta-analytic patterns emphasizing phenomenological over perceptual disruption [6]; [14].

H2. - Schizophrenia spectrum disorders will show marked impairments in temporal precision (increased variability), reflecting disrupted cortico-cerebellar and striatal integration rather than uniform biases in accuracy [7] [8] [17].

H3 - ADHD will exhibit medium-to-large deficits across timing paradigms, moderated by age and working memory capacity, particularly in supra-second and prospective timing tasks [9] [10] [15].

H4 - ASD will demonstrate reliable impairments in complex temporal processing, especially temporal order and simultaneity judgments, reflecting multisensory integration challenges [11] [24].

H5 - Acute stress will alter time perception bidirectionally depending on physiological arousal and task demands, consistent with meta-analytic heterogeneity [13] [36].

H6 -Digital behavioural rhythms (speech tempo variability, activity regularity, sleep fragmentation) will correlate with both laboratory timing performance and clinical temporal narratives, enabling predictive models of relapse and functional decline [12] [41] [45].

3. Theoretical and Neurobiological Framework

3.1 Cognitive Architecture of Subjective Time

Internal clock and population-clock models conceptualize time perception as the emergent product of distributed neural dynamics rather than a centralized chronometric module [4] [21] [29][41]. In these frameworks, attentional allocation, working memory, and motivational salience modulate the accumulation and integration of temporal information, producing variability in perceived duration.

Psychopathological theory emphasizes that these mechanisms are embedded within broader affective and personality structures, rendering temporal cognition a *structural organizer of experience* that shapes autobiographical coherence and future-oriented agency rather than a purely perceptual function [1] [3].

3.2 Neurobiological Substrates and Biomarker Networks

Neuroimaging meta-analyses using activation likelihood estimation consistently identify a distributed timing network encompassing the dorsolateral prefrontal cortex, supplementary motor area, basal ganglia, cerebellum, and hippocampal formations [16] [19]. Dopaminergic modulation within fronto-striatal loops links temporal prediction to reward anticipation and executive inhibition, providing a neurochemical bridge between timing, impulsivity, and motivational drive [25] [31].

In psychotic and neurodegenerative disorders, progressive disruption of hippocampal–frontal connectivity is associated with impaired episodic integration and temporal disorganization, clinically manifesting as identity fragmentation and diminished future-oriented agency [2] [12] [32] [33].

In Figure 1 a conceptual model illustrates subjective time perception as a transdiagnostic axis integrating four core neurobiological and psychological systems: executive control (prefrontal cortex, working memory, attention), dopaminergic regulation (basal ganglia and reward circuits), memory integration (hippocampus and episodic sequencing), and

arousal/interoception (insula and stress–emotion networks). The model maps these systems onto major clinical conditions, including depression, bipolar disorder, schizophrenia, ADHD, autism spectrum disorder, dementia, addiction, and Parkinson’s disease, highlighting time processing, time experience, and time perspective as interrelated clinical dimensions.



Figure 1. Subjective Time as a Transdiagnostic Neurobiological Axis.
Author: Bălan S.M

4. Methods: Mixed-Methods Research Design

4.1 Evidence Synthesis Protocol

The secondary evidence base was constructed through a narrative synthesis of systematic reviews and meta-analyses retrieved from PubMed, Scopus, and Web of Science (2015–2025). Inclusion criteria targeted studies reporting standardized timing paradigms or validated time-experience measures in clinical or neurodevelopmental populations [6] [15]. Primary outcomes included temporal accuracy, temporal precision, passage-of-time judgments, and time perspective profiles.

4.2 Quantitative Component

Participants:

- multi-group clinical sample (MDD, bipolar spectrum, schizophrenia spectrum, ADHD, ASD, mild cognitive impairment/Alzheimer’s disease, chronic pain, substance use disorders, and healthy controls).

Timing paradigms:

- sub-second and supra-second estimation, reproduction, and production tasks [4] [7] [16]
- temporal order and simultaneity judgments (ASD-relevant) [11] [24]

- sensorimotor synchronization (cerebellar–basal ganglia coupling) [17] [21]

Ecological measures:

- experience sampling of passage-of-time perception, boredom, stress, and rumination; passive digital phenotyping of sleep timing, activity regularity, and speech rhythm [12] [45].

4.3 Qualitative Component

Interpretative phenomenological analysis and reflexive thematic analysis will be applied to clinical interviews focusing on temporal narratives (“perpetual present,” “future collapse,” “accelerated futurity,” “fragmented chronology”) to generate cross-diagnostic temporal typologies [3] [22].

4.4 Statistical Analysis

Hierarchical linear modelling will address repeated ecological measures nested within individuals and diagnostic groups. Structural equation modelling will estimate latent constructs linking temporal precision, executive control, and affective dysregulation. Bayesian modelling will address clinical heterogeneity, while machine learning methods will explore predictive relationships between digital rhythms and relapse risk, emphasizing interpretability and cross-validation [41] [45].

5. Meta-Analytic Evidence Across Clinical Conditions

The accumulated body of meta-analytic and systematic evidence converges on the conclusion that subjective time perception constitutes a core dimension of psychopathological organization rather than a peripheral cognitive anomaly. Across diagnostic boundaries, temporal distortions emerge as structured, condition-specific configurations of attentional regulation, executive control, memory integration, and affective modulation. These patterns support a dimensional framework in which time is not merely experienced differently across disorders but is reorganized in qualitatively distinct ways that reflect the underlying neurobiological and psychological architecture of each clinical condition.

5.1 Depression

Meta-analytic findings consistently indicate moderate and reliable alterations in the subjective passage of time, while effects on objective duration judgments remain variable and strongly dependent on task structure, interval range, and cognitive load [6] [14]. This dissociation suggests that depressive temporality is expressed less as a primary perceptual deficit and more as a phenomenological and motivational reconfiguration of lived experience.

Clinically, this pattern resonates with classical descriptions of hypotimia and bradypsychia, in which affective inhibition and cognitive slowing generate a rigid, past-oriented temporal narrative marked by rumination, guilt, and a constricted future horizon [1] [2]. Time, in this context, becomes experientially “weighted,” transforming the present into a domain of emotional inertia and the future into a diminished or inaccessible space of possibility. Such temporal collapse holds direct prognostic relevance, shaping treatment engagement, recovery expectations, and vulnerability to suicidal ideation.

5.2 Schizophrenia Spectrum Disorders

Systematic reviews and meta-analyses reveal a robust and replicable pattern of impaired temporal precision, characterized by increased variability and instability in timing performance, alongside smaller and task-dependent effects on accuracy [7] [8] [17]. This dissociation points toward a disruption of the neural mechanisms responsible for temporal coordination rather than a simple bias in duration estimation.

From a clinical and phenomenological standpoint, this instability reflects a deeper fragmentation of temporal continuity, in which the sequencing of events, anticipation of future states, and integration of past experiences into a coherent autobiographical narrative are compromised. The result is a form of temporal disorganization that undermines the continuity of self-experience and intentional agency, contributing to the characteristic disturbances of identity, thought, and perception observed across the schizophrenia spectrum.

5.3 Attention-Deficit/Hyperactivity Disorder (ADHD)

Meta-analytic evidence indicates medium-to-large deficits across a wide range of timing paradigms, with strong moderation by working memory capacity and attentional control [9] [10] [15]. These findings support the clinical characterization of ADHD as a disorder not only of attention and impulse regulation, but also of temporal organization.

Subjectively, this profile manifests as a diminished capacity to maintain a stable representation of future consequences and delayed outcomes, resulting in a present-focused orientation that favors immediate reinforcement. Temporality, in this sense, becomes compressed, with extended intervals losing motivational salience. This distortion provides a cognitive and experiential foundation for patterns of disorganization, procrastination, and impaired goal persistence commonly observed in clinical practice.

5.4 Autism Spectrum Disorder

Systematic evidence demonstrates consistent impairments in complex temporal processing, particularly in tasks involving temporal order judgments and multisensory simultaneity [11] [24]. These deficits suggest that the integration of temporal information across sensory and cognitive domains represents a core area of vulnerability.

Clinically, such disruptions may contribute to difficulties in speech perception, social interaction, and predictive processing, domains in which the accurate alignment of temporal cues is essential. Temporality, in this context, is not merely a measure of duration, but a coordinating framework through which sensory input, communicative intent, and social meaning are synchronized. Alterations in this framework may thus reverberate across multiple levels of functional adaptation.

5.5 Stress, Pain and Trauma

Meta-analytic findings indicate that acute stress exerts heterogeneous effects on time perception, mediated by physiological arousal and interoceptive salience [13] [36]. Depending on the nature of the stressor and the cognitive demands of the task, individuals may experience either temporal compression or dilation.

Experimental evidence further confirms that pain reliably expands perceived duration, consistent with models emphasizing attentional capture and heightened self-awareness [17] [18]. Clinically, this temporal expansion may intensify subjective suffering, as prolonged moments of discomfort are experienced as extended intervals of distress. In trauma-related contexts, such distortions can contribute to a persistent sense of being “trapped” in the present,

with diminished access to a coherent temporal narrative that integrates past safety and future possibility.

5.6 Neurocognitive Disorders and Dementia

Meta-analytic evidence demonstrates significant impairments in timing and temporal orientation in Alzheimer’s disease and related neurocognitive conditions, supporting the clinical view of temporal disintegration as an early and central marker of neurodegeneration [12] [32] [33]. Phenomenologically, this process is reflected in the progressive erosion of autobiographical continuity, whereby the boundaries between past, present, and future become increasingly permeable. Time ceases to function as a stable organizing axis of identity, and personal history fragments into isolated experiential islands. Clinically, this temporal collapse underlies the profound loss of autonomy, narrative coherence, and relational continuity characteristic of advanced stages of dementia.

5.7 Addictions and Impulsivity

Systematic reviews reveal altered temporal discounting and timing deficits across substance use disorders, linking dopaminergic dysregulation to impaired future orientation and increased relapse vulnerability [19] [20] [21] [25].

In this context, temporality is reshaped into a reward-dominated structure in which immediate gratification eclipses long-term consequence. The future is not merely undervalued but experientially attenuated, reducing its motivational force in guiding behavior. Clinically, this temporal contraction provides a unifying framework for understanding cycles of craving, loss of control, and repeated relapse, situating them within a broader disruption of temporal agency rather than solely within deficits of willpower or insight.

The transdiagnostic structure of temporal distortions across major clinical conditions, including their neurobiological substrates and clinical implications, is synthesized in Table 1.

Table 1. Meta-Analytic Profile of Temporal Distortions Across Clinical Conditions (Bălan S.M.)

Clinical Condition	Dominant Temporal Distortion	Meta-Analytic Pattern	Primary Neurobiological Systems	Core Cognitive Mechanisms	Clinical & Prognostic Implications
Depression	Slowed passage of time; future collapse; past fixation	Moderate and consistent effects on subjective passage of time; variable and task-dependent effects on objective duration judgments [6] [14]	Prefrontal cortex–hippocampus; limbic networks	Rumination; reduced executive flexibility; affective inhibition	Suicide risk assessment; treatment engagement; prognosis of chronicity
Schizophrenia Spectrum	Temporal fragmentation; impaired sequencing; unstable anticipation	Robust impairments in temporal precision (high variability); smaller, paradigm-dependent effects	Cortico-cerebellar circuits; striatum; prefrontal cortex	Disrupted predictive processing; weakened temporal binding	Functional outcome prediction; self-disorder profiling; rehabilitation planning

Clinical Condition	Dominant Temporal Distortion	Meta-Analytic Pattern	Primary Neurobiological Systems	Core Cognitive Mechanisms	Clinical & Prognostic Implications
		on accuracy [7] [8] [17]			
ADHD	Temporal compression; present bias; “time blindness”	Medium-to-large deficits across paradigms; strong moderation by working memory and age [9] [10] [15]	Front striatal attention networks; dopamine systems	Impaired prospective timing; working memory limitations	Academic/workplace functioning; intervention personalization
Autism Spectrum Disorder (ASD)	Disrupted temporal order; multisensory asynchrony	Consistent impairments in complex timing tasks; weaker effects in basic duration judgments [11] [24]	Multisensory integration networks; superior temporal cortex; cerebellum	Impaired temporal binding; reduced predictive alignment	Communication and social cognition interventions
Stress / Trauma	Time dilation or compression; heightened present salience	Heterogeneous, arousal-dependent effects across tasks [13] [36]	Insula; limbic system; hypothalamic–pituitary–adrenal axis	Interoceptive amplification ; attentional capture	PTSD risk monitoring; crisis intervention
Chronic Pain	Time dilation; prolonged present	Experimental confirmation of expanded perceived duration [17] [18]	Salience networks; insula; prefrontal cortex	Sustained attentional focus on bodily states	Pain management outcomes; cognitive-behavioral targeting
Neurocognitive Disorders / Dementia	Temporal disorientation; autobiographical erosion	Significant impairments in time perception; early diagnostic marker [12] [32] [33]	Hippocampus; frontoparietal networks	Episodic memory breakdown; sequencing failure	Early diagnosis; caregiver planning; autonomy assessment
Addictions / Impulsivity	Temporal discounting; future attenuation	Medium-to-large timing and discounting effects; relapse vulnerability [19] [20] [21] [25]	Dopaminergic reward systems; basal ganglia	Reward-driven present bias; weakened future valuation	Relapse prevention; motivational interviewing

Continuing Table 1. Meta-Analytic Profile of Temporal Distortions Across Clinical Conditions. (Bălan S.M.)

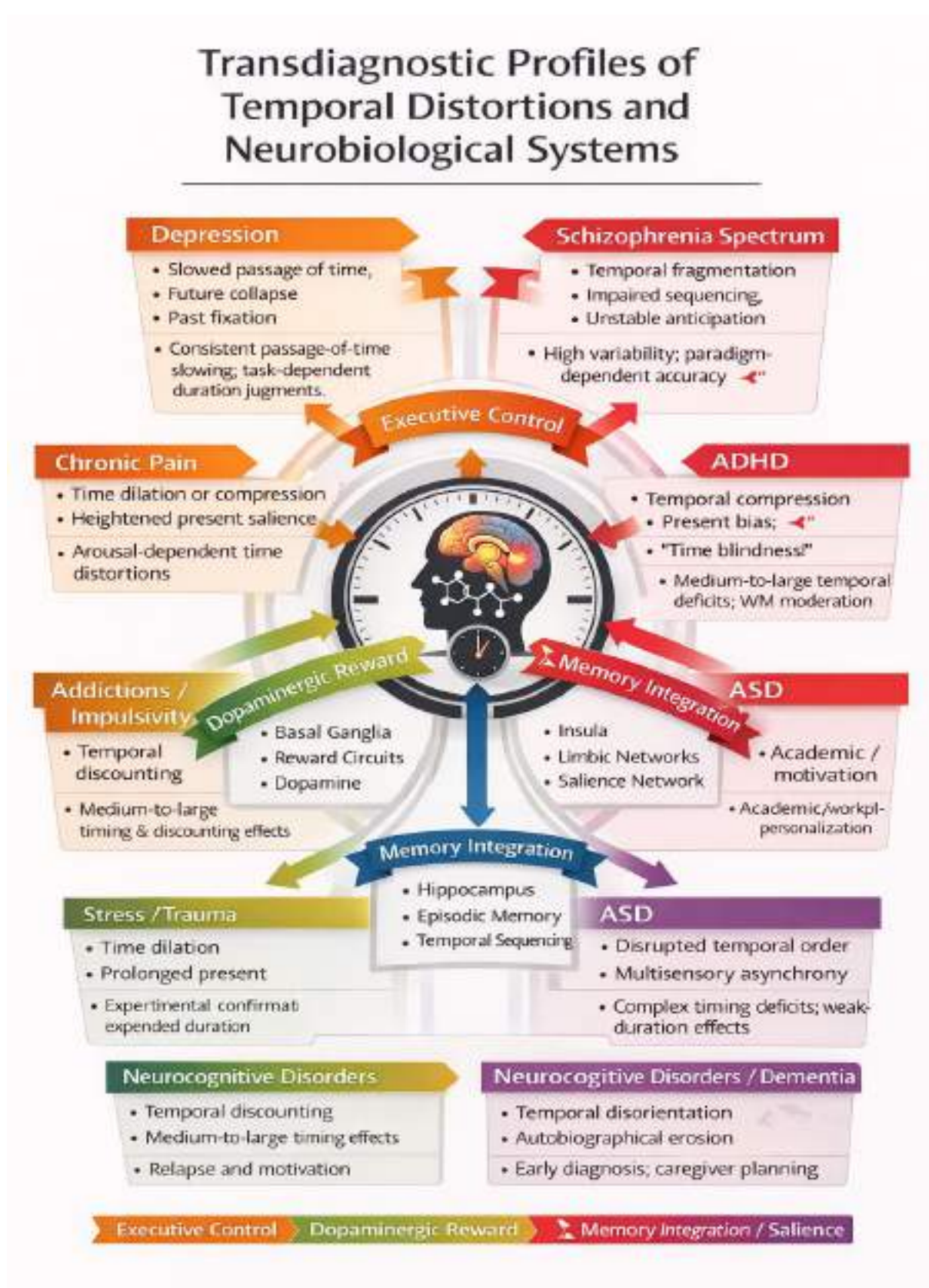


Figure 2. Transdiagnostic Profiles of Temporal Distortions and Neurobiological Systems. Author: Bălan S.M using Canva

Figure 2 synthesizes the transdiagnostic profiles of temporal distortion across major clinical conditions by mapping disorder-specific temporal phenotypes onto four core neurobiological axes: executive control (prefrontal cortex, attention, working memory), dopaminergic reward regulation (basal ganglia and motivational circuits), memory integration (hippocampus and episodic sequencing), and interoception/salience (insula and limbic networks). The figure visually integrates meta-analytic evidence and clinical interpretation, illustrating how distinct psychiatric and neurocognitive conditions converge on shared neural systems while expressing condition-specific patterns of temporal compression, dilation, fragmentation, and future attenuation.

6. Phenomenological and Didactic Exemplification

The case phenomenological dimension of subjective time provides a crucial bridge between objective neurocognitive mechanisms and the lived reality of clinical experience. While experimental paradigms and neuroimaging studies elucidate the structural and functional substrates of temporal processing, it is through individual narratives and symbolic representations that the existential significance of temporal disruption becomes fully intelligible within therapeutic and educational contexts.

The classic case of H.M. offers a paradigmatic illustration of the dependence of autobiographical continuity on hippocampal-mediated temporal integration. Following bilateral medial temporal lobe resection, the preservation of procedural learning alongside profound anterograde amnesia resulted in a subjective existence confined to a “perpetual present,” in which the capacity to situate experiences within a coherent temporal narrative was fundamentally compromised [32] [33]. This dissociation empirically anchors the clinical insight that identity continuity is not merely a function of personality traits or perceptual awareness, but a dynamic process sustained by the ongoing integration of experience into a temporally ordered autobiographical framework.

Cotard’s syndrome represents an extreme and conceptually illuminating counterpoint, in which temporal organization collapses not through neurocognitive amnesia but through nihilistic delusion. In this condition, patients may report the subjective annulment of existence itself, accompanied by a profound disruption of chronological continuity and personal agency [22]. Temporality is not simply distorted but negated, transforming the self into an entity perceived as suspended outside the flow of lived time. Clinically, this phenomenon underscores the intimate relationship between temporal coherence, self-representation, and affective meaning.

Within didactic and translational domains, cinematic representations such as *Memento*, *The Father*, and *Still Alice* serve as powerful mediating tools that externalize the subjective experience of temporal disintegration. By structurally mirroring the phenomenology of amnesia, dementia, and identity erosion, these narratives render abstract neuropsychological constructs experientially accessible to students and practitioners. Empirical work in medical education indicates that such representations enhance empathic engagement, reflective capacity, and ethical sensitivity, facilitating a deeper integration of scientific knowledge with the human realities of clinical care [15] [21].

Collectively, these phenomenological and didactic exemplars demonstrate that subjective time is not solely a variable to be measured, but a lived dimension through which suffering, agency, and recovery are negotiated. Their integration into clinical training and research

frameworks reinforces the necessity of maintaining a dialogue between empirical rigor and experiential understanding in the advancement of mental health sciences.

7. A Transdiagnostic Model of Temporal Dysfunction

Across psychiatric and neurological conditions, temporal disturbances converge on shared mechanisms:

1. executive and attentional control deficits (ADHD, depression, anxiety) [9] [36];
2. dopaminergic fronto-striatal dysregulation (mania, addiction, Parkinsonism) [25] [31] [34] [35];
3. hippocampal–prefrontal memory integration failure (dementia, psychosis, amnesia) [12] [32] [33];
4. interoceptive and arousal-based modulation (stress, pain, trauma) [13] [17] [36].

This convergence supports a dimensional framework distinguishing *time processing*, *time experience*, and *time perspective* as interrelated but dissociable clinical targets [13] [38].

8. Future Direction

Longitudinal neuroimaging and digital phenotyping studies should examine whether temporal precision variability predicts functional decline in schizophrenia and neurodegeneration [7] [12] [17]. Computational psychiatry models grounded in predictive processing and free-energy principles may formalize temporal distortion as a failure of temporal prediction error minimization [41] [43]. Cross-cultural validation of temporal phenomenology remains a critical gap, particularly for time perspective instruments [13].

Conclusion

The present study has fulfilled its central objectives by systematically addressing the core research questions and empirically grounding its theoretical framework within convergent meta-analytic, neurobiological, and phenomenological evidence. The synthesis of high-level reviews across affective, psychotic, neurodevelopmental, addictive, and neurocognitive conditions demonstrates that subjective time perception constitutes a robust transdiagnostic dimension of mental functioning rather than a peripheral or epiphenomenal feature.

The central research questions were answered through the identification of consistent, condition-specific temporal phenotypes that map onto shared neurobiological systems of executive control, dopaminergic regulation, memory integration, and interoceptive salience. This convergence supports the proposed dimensional model in which disturbances of temporal precision, temporal experience, and time perspective reflect coordinated disruptions across distributed neural networks.

The formulated hypotheses were largely confirmed. Evidence indicates that depressive states are primarily characterized by alterations in lived temporal experience rather than uniform deficits in perceptual accuracy; schizophrenia spectrum disorders exhibit marked impairments in temporal precision and temporal coordination; ADHD demonstrates medium-to-large timing deficits moderated by working memory and attentional capacity; autism spectrum disorder presents consistent vulnerabilities in complex temporal integration; and addiction-related and stress-related conditions show pronounced distortions in future orientation and present salience driven by dopaminergic and arousal-based mechanisms.

Beyond validating these hypotheses, the study advances a clinically actionable research framework that integrates laboratory-based timing paradigms, ecological digital phenotyping, and qualitative phenomenological analysis. This integrative approach positions subjective time perception as a promising biomarker for diagnostic refinement, prognostic modelling, and personalized intervention strategies across psychiatry and clinical psychology.

In doing so, the paper contributes to a growing translational perspective in which temporal cognition is no longer viewed solely as a cognitive construct, but as a foundational axis of human agency, identity continuity, and ethical clinical practice. The findings underscore the necessity of maintaining a dialogue between empirical rigor and lived experience in the advancement of contemporary mental health sciences.

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DIGITAL EQUITY IN THE CONTEXT OF SOCIAL VULNERABILITY: A CRITICAL SYNTHESIS OF RECENT LITERATURE

Assoc. Prof. Ioana-Eva CĂDARIU Ph.D.¹, Prof. habil. Ovidiu Florin TODERICI Ph.D.², Prof. habil. Loredana-Ileana VÎȘCU Ph.D.³, Prof. habil. Dana Veronica RAD Ph.D.⁴

^{1,3}“Tibiscus” University of Timișoara, Institute for Psychotherapy, Psychological Counseling and Clinical Supervision (IPCS);

^{2,4}“Aurel Vlaicu” University of Arad”, Romania

Corresponding author: Ioana-Eva Cădariu: cadariuioanaeva@yahoo.com

Abstract

This article intends to contextualize the relationships between technology, vulnerability, and digital equity to offer a critical analysis of recent studies on the topic of digital inclusion of vulnerable groups. By discussing a qualitative review of international studies on the topic of digital inclusion, this analysis will aim to emphasize that access is not a sufficient condition to achieve inclusion in a technological environment, as digital participation also needs supportive structures, user-friendly designs, education, and involvement of marginalized groups in the process of digital inclusion. This analysis of recent studies on digital inclusion shows that, although digital technologies can utilize new capabilities to promote greater autonomy, communication, and well-being, they can act as vehicles of certain pre-existing inequalities if they are not appropriately sensitive to social diversity. This article argues that the concept of digital inclusion needs to be contextualized as a multidimensional social process that is a nexus of innovation, education, and equality — where technology is utilized as a means of empowerment rather than as a source of exclusion in the digital age.

Keywords: digital inclusion; digital equity; vulnerable groups; assistive technologies; social justice

Introduction

Over the past couple of decades, digitalization has emerged as one of the major agents of change in the social, pedagogical, and cultural domains. Nevertheless, the positive outcomes of digitalization are not enjoyed by equal sections of society [1]. This gives rise to what is termed as digital inequality — a new type of social exclusion that perpetuates existing power relations, classes, as well as cultural capital [2]. It is in this new paradigm that the concept of digital equity has assumed primacy as a new policy mandate not only in terms of technological access but also in terms of participation in the virtual world [3].

As Prensky (2001) argues, the terms “digital natives” and “digital immigrants” represent a crucial point of demarcation between generations in the way people interact with technology. Nevertheless, more recent studies propose that this kind of dualism is overly simplistic, neglecting factors such as education, class, and culture, which condition people's effective use of technology in a variety of ways [4], [5]. In a recent empirical inquiry involving seniors,

Hargittai & Dobransky (2017) demonstrate that people of this age group are not as divided in terms of technological proficiency as often assumed, as the gap between seniors' use of technology is in fact contingent upon digital literacy skills as well as technological confidence — issues that are inextricably intertwined with experiences of social exclusion.

However, Tsatsou, Youngs, & Watt (2017) also state that digital inclusion is not only a process of gaining technological skills and competency but is also a process of forming a digital identity that leads to social inclusion. This is evident in a study where digital literacy is found to impact one's identity, specifically in marginalized groups who experience in the virtual world a form of expression. This is in consonance with the assertions of Noble & Tynes (2016), where the Internet is not a level-playing field where everything is equal — it is a reflection of gender, race, and class — thereby making digital inclusion not only a process of technological competency but of social justice as well.

Concerning the internet access of people with disabilities, authors Scholz, Yalcin, & Priestley (2017) highlighted that people with disabilities experience not only technological barriers in internet access but also relational as well as attitudinal barriers in that those people experience subtle barriers in relation to discrimination, a lack of accessible technological support, as well as a lack of a supportive online culture. This relational focus on the issue of internet access is broadening the traditional concept of digital divide studies, which primarily focused on technological barriers, including internet access [6].

“The experience of migration and refuge highlights a new set of vulnerabilities in a digital age.” Here, Lloyd, Kennan, Thompson, & Qayum (2013) observe that in response to new “information landscapes” in host societies, refugees develop new forms of informational literacy. This extends well beyond the use of technology; rather, informational literacy entails skills such as source criticism, dealing with uncertainty, and trusting in online environments [7]. This suggests that a range of online tools, such as digital storytelling and online learning initiatives, can act as powerful instruments of social integration as well as sources of psychological well-being for migrants. By sharing experiences as well as education, online communities help alleviate loneliness [8].

At the same time, Kuneva & Hough (2023) draw a focus on the issue of digital inclusion of refugees and migrants that needs not only technological support, as a lack of transparency, fear of surveillance, as well as a lack of data protection, can be a factor that is discouraging people from joining online services in a way that is referred to as a paradox of exclusion in a world that is interconnected [9]. Supporting this idea, the next point that shall be raised is that of digital skills presented in the contribution of Potocky (2021). This point is important as digital skills are a factor that is leading refugees towards education, employment, as well as towards accessing various social services [10].

Collectively, these studies make it apparent that digital equity cannot be observed as a technological issue in a singular focus. Instead, there is a need to consider digital equity in consideration of technological, social, education-based, as well as cultural factors as well [9] [10]. As such, the internet represents a location where the separation of equality in the offline world is reproduced online, in addition to online inequality having the ability to represent a source of empowerment [2] [3]. Ultimately, the online inclusion of vulnerable populations will require a combination of technological expertise, social capital, institutional trust, as well as identification [9] [10].

Assistive Technologies and Digital Equity: A Synthesis of Recent Studies

Grounded in the theoretical framework that emphasizes the relationship between digital competences, social capital, and citizen participation among vulnerable populations, recent literature offers both empirical and conceptual investigations on how assistive technologies and digital solutions act as means of either diminishing and/or increasing social inequality. In this respect, contemporary studies cover a broad range of issues — ranging from inclusive education to digital health, information access, as well as social justice — and emphasize that the processes of digitalization in no way pertain to a vacuum in terms of the user environment [11] [15].

A relevant piece of research conducted by Abbott, Brown, Evett, & Standen (2014) analyzes the development of supporting technologies over time, underlining the central importance of these technologies in facilitating inclusion in education as well as in the digital age, specifically in respect to people with disabilities. In the context of this review, supporting technologies are defined as "a wide range of technologies — extending from mobility aids to orientation aids, adaptive software, alternative keyboards, screen readers, and augmentative communication software — that could potentially compensate individuals who experience sensory, motor, or cognitive difficulties." Abbott, Brown, Evett, & Standen consider supporting technologies as a "crucial stepping stone in assisting people with disabilities integrate into education and working environments," as long as supporting technologies are designed to universal standards and customized according to the needs of each user [11].

It is stressed that, in spite of progress that has been attained in increasing access to the use of these resources, digital disparities continue to exist, particularly between those with severe disabilities and the rest of the population. It is suggested that simple provision of technology is not sufficient to provide digital inclusion since there are various barriers that limit the successful use of these technologies. Lack of appropriate training is particularly important in making technology use a source of frustration rather than a source of inclusion [11].

One of the most important findings that is brought out in this study is that the development of these technologies has been done in a way that is not directly involved by the beneficiaries themselves. Abbott et al. emphasize a more participatory way in which people with disabilities, teachers, therapists, as well as developers of technologies, come together in a co-creative process to develop usable products. This allows not only greater efficiency of the technologies but also enhances the feeling of competency of the people using the technologies [11].

At the same time, the authors draw particular attention to the importance of a supporting education and institutional framework that enables beneficiaries to continue benefiting from these technologies in the long term. It is not sufficient to integrate these technologies in schools, in rehabilitation centres, as well as in social services, because there is a need to train teachers to adjust ways of education as well as communication to the needs of those people [11].

From a political and social point of view, this article argues that accessibility technologies must be considered a right of access rather than a technological privilege. A greater investment in scientific research, as well as a greater commitment to software development, could help limit the gap in digital inequality and lead to a greater inclusion of disadvantaged groups in society. As a conclusion, authors assert that a holistic approach to digital inclusion is a foundation that is built upon dimensions of accessibility, education, and collaboration to ensure that society becomes more inclusive [11].

Following the tradition of studies initiated by Abbott et al. (2014), who revealed that assistive technologies can address the gap between exclusion and participation, Amante, Hogan, Pagoto,

& English (2014) apply this analysis of a particular field to the field of health in order to understand how patient portals can either facilitate or hinder vulnerable individuals' access to health information. This systematic review describes a critical point of view of the field of eHealth literacy, which remains a cornerstone of addressing issues associated with inequality in terms of diseases, age, as well as socioeconomic factors [12].

As a disorder that demands continuous monitoring by the afflicted individuals themselves, the extent to which sufferers can effectively utilize online platforms in diabetes care is investigated in this study. It is illustrated that, in spite of various benefits that people with diabetes can derive from online activities, elderly individuals with low education levels as well as those belonging to the impoverished population face severe difficulties in operating online platforms, thereby undermining the treatment effects obtained via online diabetic management [12].

In accordance with the findings of Abbott et al. (2014), Amante et al. reiterated that technological access alone will not suffice if training, motivation, and social factors are not taken into consideration simultaneously. Therefore, barriers such as issues of trust, risk perception, and technological anxiety act as decisive factors that inhibit seniors as well as individuals with a chronic condition from making use of the online portal. This particular point tends to reinforce the notion that the issue of digital inequality is often a reflection of existing social inequality [12].

Moreover, the authors offer a sophisticated discussion of the psychosocial factor that comes into play in the use of health platforms, indicating that those who enjoy a positive experience with medical personnel as well as high levels of self-efficacy experience greater adoption of these tools. Conversely, individuals who fear a lack of human contact in digital care will not use technology-based solutions, thereby contributing to a double exclusion experience that is both digital and medical in nature [12].

As suggested in the approaches that consider inclusion in special education, this article emphasizes the importance of having a customized interface that is easily accessible by people with visual or motor disabilities. This integration of the two paradigms of accessibility in education and in the field of communication in health issues signifies that interdisciplinarity is a necessity in the development of online platforms [12].

Nevertheless, as highlighted in the analysis, the adoption of these online platforms is influenced not only by institutional factors, such as the hospital's policy, medical personnel's training, but also by cultural factors, that is, by social representations of the "digital patient" (in particular, those individuals with a lack of digital literacy can see online platforms as tools of surveillance rather than as support tools, thereby necessitating a particular kind of communication from the medical staff). [12].

Accordingly, this review reveals that the factor of successful technological implementation in a medical setting is a combination of not only technology, but also the possible influence of the psychosocial capital of those individuals involved in medical care — their trust, skills, social support, as well as a feeling of informational security. Following the studies of Abbott et al. (2014), covering inclusion in education, this article shows that a combination of the same factors — cooperation, accessibility, participation — is of utmost importance in a medical field as well. Therefore, this review suggests that a valuable contribution in this field is offered by Amante et al. (2014).

Expanding on the issue of equal digital access to health care discussed by Amante et al. (2014), de Lusignan et al. (2014) also discuss the various factors relating to equal access of patients to the use of electronic health records (EHR) as well as online support. This review

interprets various factors that restrict, promote, as well as raise ethical issues around equal digital access, to develop strategies that will help in enhancing the independence of those who use online health technologies [13].

According to the authors, the use of digital medical records is a paradigm change in the field of health systems, as this new generation of medical records enables the active involvement of patients in managing their medical data. Nevertheless, varying levels of digital and medical literacy can generate new barriers to this form of equality. Patients with chronic pathologies, elderly people, as well as individuals with a lower education level and income, will not readily utilize medical records as a result of confidentiality issues, misconceptions of medical terminology, as well as missing technical support [13].

In line with the findings of Amante et al. (2014), which identified the importance of digital literacy skills in the usage of medical internet portals, this review will maintain that digital autonomy in the field of healthcare is contingent upon a synergy of technological, institutional, and relationship factors. De Lusignan et al. point out that where unique digital access is enabled, this needs to be backed by a supporting institutional culture that values transparency and collaboration in order to ensure that trust is not only built through digital means, but through a supportive relationship with the caring professionals as well [13].

What is peculiar about this particular study is that issues of digital access as well as the ethical dimension of that access are analyzed. This is important since transparency in information is perceived to have a double edge in this way: on one hand, transparency of information is associated with increased feelings of empowerment of the patient; on the other hand, transparency of information is often a source of anxiety, particularly where the complexity of medical information is accessed inappropriately [13].

In a way that is also convergent with the analysis of inclusive education conducted by Abbott et al. (2014), the authors recommend that the design of the health system be participatory in nature, involving patients from the point of development and pilot-testing of platforms. Through this, not only will the needs of the vulnerable population be identified in terms of accessibility, but solutions will also be fashioned that suit varying levels of digital as well as medical literacy [13].

Nevertheless, the importance of training medical staff in making digital access more equitable is underlined in this issue as well. It is imperative that these medical professionals act as facilitators in between technology and patients. Accordingly, instead of a conventional technological change in the digitization process, a new relation of medical practice is formed where vulnerable populations are assisted constantly in managing their data as well as medical decisions [13].

Hence, this review emphasizes that a combination of technological infrastructure, digital education, as well as relational support, is imperative in addressing digital equality in the medical field. As opposed to a technocentric model, the authors of this article propose a new integrative model of a socio-technological nature that focuses on the role of the patient in the innovation process. Finally, the article by de Lusignan et al. (2014) is a groundbreaking piece of research in understanding how a positive use of electronic medical records can be a source of digital equality in medical care for the most vulnerable groups of patients [13].

Moving on from the topic of equity in the digital world and the inclusion of vulnerable groups in technological spaces, Mubarak (2015) suggests a wide-ranging theoretical framework that sees the digital divide not only in terms of access, but as a much more intricate phenomenon of a social kind that is linked to issues of power relations, cultural capital, and inequality. It is

suggested that where the digital divide is not approached in a way that is inclusive, the same kind of exclusion applies in a tangible way that is experienced in offline social spaces [14].

While previous studies, as conducted by Amante et al. (2014) and Lusignan et al. (2014), identified issues of access to medical care as well as technological interfaces, Mubarak instead examines the socio-economic framework that shapes people's use of technology. Mubarak shows that the digital divide is not a simple divide between those people that "have" access to the internet as opposed to those people that "do not," as suggested in earlier studies [14]. Instead, he argues that the digital divide is a stratified phenomenon that is shaped by education, income, gender, as well as geographical location in a cumulative way that determines the use of technology.

Introduced in a way that converges with the reasoning of Abbott et al. (2014), the author highlights the need for technological contextualization in that simply introducing aid tools or online platforms is not sufficient, since not only is access to technology required, but skills in use, positive attitudes, and a collaborative technological culture are also important. Mubarak uses the term "nerves of the digital divide" to characterize the various invisible layers that coexist between economic, education, and symbolic barriers, which, according to Mubarak (2015), must be tackled at the same time in inclusion initiatives and technological education.

To complement the perspectives that focus on the digital health theme, this study presents a holistic approach to information inequality issues, highlighting that individuals in marginalized groups, including migrants, ethnic minorities, people with disabilities, or those in rural areas, often experience a range of barriers that are not only technological in nature, including a lack of trust in digital systems, a lack of native language content, as well as a lack of representation in digital culture. Therefore, digital exclusion extends beyond social exclusion in terms of the diversity of the forms of vulnerability [14].

At the same time, Mubarak makes a particularly important point in considering the relationship between social capital and digital access, demonstrating that those people who are well-connected in a social network are particularly likely to use technology either as a means of education or as a way of advancing a career, in contrast to people who are shut away in a situation of structural precariousness. This particular theoretical point has a number of highly important implications in terms of public policy [14].

In a reaction that is complementary to the socio-technological approach outlined in de Lusignan et al. (2014), the author stresses that inclusive technology governance is imperative to ensure that various stakeholders, including community groups, NGOs, as well as learning institutions, play a role in shaping solutions that are participatory in nature. This is in opposition to those approaches that apply a top-down strategy that is devoid of technological innovation, as a result of which a lack of digital feeling ensues (Mubarak, 2015).

Accordingly, Mubarak's (2015) contribution to this topic presents a critical stance towards the issue of digital equity in a way that specifically emphasizes the connection between technology and issues of social justice. Moreover, in opposition to instrumental interpretations of digitization, this particular contribution suggests a humanistic approach that is focused on participation and transformation, building a technological process that acted as a means of liberation rather than as a subtle barrier. Moreover, this theoretical contribution extends the comprehension of digital inclusion [14].

Continuing with the concern of structural barriers that inhibit equal access to digital information, Thompson, Reilly, & Valdez (2016) offer an integrative approach to the difficulties that inhibit the utilization of Personal Health Records (PHRs). This systematic review is in accordance with studies that stated that digital technologies in the field of medicine cannot be

deemed impartial since they are influenced by a set of structures, processes of work, and power relations between medical practitioners and recipients [15].

As de Lusignan et al. (2014) found that barriers at the individual level, including digital literacy skills, lack of trust, influence access, Thompson et al. consider barriers in the wider healthcare system at a macro-level in terms of interdependence between technological infrastructures, work processes, and culture. They demonstrate that, in the absence of a technology-friendly environment that benefits both the user and the software, the user, as well as the professionals, is faced with the problem of information overload, lack of interoperability, as well as digital bureaucracy [15].

In a way that is convergent with Mubarak (2015)'s thoughts on the structural aspect of digital exclusion, this article suggests that vulnerable people are disproportionately affected by systemic issues such as a lack of data standardization, incompatibility, as well as a lack of managerial support. It seems that seniors as well as people with intellectual disabilities, as well as individuals with a disadvantaged socioeconomic status, experience a double challenge in that, on one hand, they struggle with technologically advanced interfaces that require high-level technological expertise, and on the other hand, a rigid medical system that does not offer them training to operate the technology [15].

It is also observed by the authors that medical professionals face the same issue of having to interact with fragmented systems, as well as enter redundant information manually into the systems, thereby leaving less time to address patients. This issue, termed as technological overload, leads to increased occupational stress as well as a negative impact on job satisfaction, ultimately affecting medical care.

Ironically, technology that is expected to facilitate collaboration between various stakeholders ultimately leads to a gap between them, including those who require appropriate care [15]. Nevertheless, the authors continue to discuss the ethical-social issues that come to mind upon considering the use of electronic records, asserting that transparency in information will only be beneficial if data-protection standards are well set in place combined with appropriate expert training in digital confidentiality.

Without these standards in place, people in vulnerable circumstances are likely to be resistant to the use of such technology since they will see it as a source of danger to the confidentiality of their private information, including medical data [15].

Diversity and Vulnerability in the Digital Age: From Exclusion to Participation

In a society characterized by technological polarization and enduring inequalities, Panayiota Tsatsou (2022) advocates a qualitative analysis of benchmarking the digital inclusion of vulnerable groups in society to examine the impact of intersectionality — defined as the interdependence of identities and structures on people with disabilities, older people, and ethnic minorities. This is because, according to the author, the presence of technological tools in people's lives does not necessarily ensure digital inclusion, since cultural factors, stigma, as well as life events, have a profound impact on individuals [16]. A qualitative approach conducted through focus groups enabled this strategy to capture intergroup dynamics and discourses emerging around the notion of vulnerability and technology. From a theoretical stance, Tsatsou defines vulnerability not only as a limitation of a structure, but as a condition of humanness that unleashes the power of empathy and morality — a notion which is never approached in studies around digital exclusion [16].

The data demonstrate that digital use is a practice that varies greatly between groups. Persons with disabilities use technology as a means of achieving independence and overcoming stigma, employing medical apps, online support groups, and accessible technology that enables them to tackle everyday tasks and reconstruct a new identity that overcomes the constraints of their bodies. Compared to this, ethnic minorities use digital media as a means of inclusion in culture, communication, and orientation in the new society around them, yet are subject to language barriers, a lack of financial access, as well as discrimination. As a contrast, seniors use technology as a means of advancing their personalities and achieving continuity in existence, employing digital tools in education, communication, and the maintenance of a full life after retirement, yet showing hesitation towards the speed of technological progress and a lack of human contact [16].

Conclusions

What emerges from an integrative analysis of this literature is that digital inclusion is not simply a technological issue, but a complex social phenomenon that intersects with access to resources, skills, attitudes, and support. In general, the literature suggests that assistive technologies are only capable of addressing issues of inequality if they are combined with education, training, and design strategies that are sensitive to human diversity [11] [16].

Moreover, all the above studies point towards the notion that digital literacy is a crucial factor that determines equity. Also, a lack of digital skills contributes to vulnerability in whatever form that vulnerability may take, that is, disability, old age, as well as marginalized socio-economic groups. It is in this respect that studies point towards the notion that there is a need to apply an ecological framework in addressing digital inclusion, where technological, education, as well as attitudinal barriers are interconnected. Also, Thompson et al. (2016) point towards the notion that not only is the user at risk of a fragmented digital system, but a professional is as well.

Concerning practical application, the integration of this body of works presents a strategic approach that enables relevant public policies and education initiatives targeting digital equity. This strategy entails:

- the creation of user-friendly digital platforms that can be accessed by everyone;
- supporting adaptive digital literacy skills through trainings offered according to skill levels and forms of vulnerability;
- development of intergenerational learning environments in which seniors, youth, as well as people with disabilities, can learn from one another;
- supporting applied research in the psychosocial effects of technologies on quality of life.

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DIGITAL APPS AND MENTAL HEALTH: TOWARD INCLUSIVE AND PARTICIPATORY INNOVATION

Assoc. Prof. univ. Ioana-Eva CĂDARIU, Ph.D. Prof. univ. habil. Ph.D. Felicia ANDRIONI Ph.D., Prof. univ. habil. Loredana-Ileana VÎȘCU* Ph.D.

“Tibiscus” University from Timișoara, Romania.

Corresponding author: Ioana-Eva Cădăriu: cadariuioanaeva@yahoo.com

Abstract

The incorporation of technology in mental health studies and practices is both an opportunity and a challenge towards achieving equity among groups. This paper examines the transformative role of technology-based solutions, such as web-based and mobile-based solutions, in improving accessibility, engagement, and overall equity of mental health support. Research findings indicated that to achieve technology-based equity in mental health support among the rural and minority populations, there is a need to heavily invest in infrastructure and adapt technology-based solutions to be culturally responsive. At the forefront of this effort is community-based participatory research (CBPR) as a methodology that promotes the co-production of technology-based solutions with and for the community. It is with this mechanism that innovation not only incorporates the advancement of technology but is also embedded with high theoretical grounding. This convergence means that technology-based solutions to mental health not only represent technological advancement but also sustainable systems of resilience and well-being among diverse groups. This paper introduces the role of inclusiveness as a critical component underlying the technology transformation of mental health services.

Keywords: digital mental health, participatory research, mental health equity, inclusivity

Introduction

As technology is increasingly embedded in people's day-to-day experiences, it is changing the way in which people gain information and communicate with each other as well as experience health and social services [1].

From the mediatization theory's point of view, the media is no longer merely a transparent communication medium but a force with the potential to transform the nature of human interaction and practices [1]. This background information draws attention to the effect that “the media logic of visibility, connectivity, and immediacy is not simply a media trait. It is restructuring education, politics, medicine—and hence the production of knowledge itself” [1]. For this reason, online media is stated to be “social infrastructures that determine perception, participation, and production of collective meaning” [1].

In this regard, mental health treatment among adolescents is gradually migrating to online environments that are marked with accessibility, anonymity, and engagement [2]. Different empirical studies have verified that adolescents have been attracted to online assistance because of their demand for flexibility and the confidentiality that is offered online with regard to emotional matters [2].

In particular, online platforms are suitable environments in which to take advantage of services related to mental health care for adolescents due to their instantaneous availability of psychological information [3].

These practices can be described as mediatization because they exemplify mediation of the therapeutic interaction through technology instead of bodily co-presence [1].

Apart from this, there have been findings to support that computerized cognitive behavioral therapy and mobile health applications have been proven to be effectual in improving mental health in adolescents [4]. These can be employed with fewer location and economic limitations for the purpose of preventive education and early intervention [4].

At the same time, however, scientific results show that technology can cause potential cognitive overload and decreased well-being levels, implying that technology should be employed under well-structured and principles-based guidelines [6]. This means that technology and digitalization carry with them potential benefits in terms of empowerment and dependency related to emotional regulation [6].

Based on such findings, the role played by youth workers at non-governmental agencies in South Africa to support health among young individuals through the medium of digital media technology has been explored by Chauke and Kakuru (2025).

From their qualitative study among twenty respondents who came from four provinces, the health education and psychosocial support platforms they have identified to be used mainly include Microsoft Teams, TikTok, WhatsApp, and YouTube [6].

Microsoft Teams facilitated online counselling that addressed anxiety and stress associated with the COVID-19 pandemic. This encouraged continued care in settings with limited direct accessibility [6]. The adoption of TikTok and YouTube platforms made it possible to communicate health information in a more entertaining way to engage youths [6].

Additionally, the WhatsApp service offered direct interaction as well as peer learning and the formation of online communities that encouraged young people's self-efficacy and agency [6]. Despite this, the authors noted data costs and online literacy as challenges to online health intervention services among young people [6].

In general, the above findings evidently confirm the effectiveness of mediatization theory in examining the impact of online spaces on working patterns and support structures among young people [6].

It is evident through overall empirical evidence that digital media can be employed to enhance the effectiveness and accessibility of mental health services among adolescents with the help of proper training and ethical standards [2] [4].

As such, online platforms such as TikTok, YouTube, WhatsApp, and Microsoft Teams not only have the purpose of communication facilitation but can also form transformative spaces for empowerment, prevention, and growth [6].

In the end, such complementary perspectives highlight the view that media technology is no longer a tool for information transfer but is a dynamic space actively shaping health, identity, and social relations among the young age group [1] [5].

Emerging Directions in Youth Digital Well-Being Interventions

Potts et al. (2025) provide a broad overview of the current impact technology is having on the psychological care offered to those between 16 and 25.

As mentioned in the paper, online spaces can increase accessibility to mental health care and the associated stigmas can be eliminated with a therapeutic framework that is aligned with online behavior patterns among young people [7].

This scoping review analysed more than 13,000 records and included 145 empirical publications that showed a rapid proliferation of this still young research field [7].

Many efforts were related to well-being, depression, anxiety, or stress. All such activities were done online or through mobile applications [7].

As mentioned in Potts et al. (2025), cognitive behavioural therapy remains to date the model of choice that is commonly combined with mindfulness or exercises related to positive psychology. The components of the intervention included psychoeducational activities or emotional/self-regulation goals [7].

Findings in similar studies confirm the above results. Kahl et al. (2020) demonstrated that ReachOut.com, which is not a structured online service, resulted in increasing help-seeking and reducing distress in adolescents. Also, Finlay-Jones et al. (2023) found that web-based self-compassion increased well-being and reduced self-criticism in adolescents with chronic medical conditions.

In addition, results obtained by Sanci et al. (2019) revealed that a web-based support tool named LINK successfully linked young individuals to suitable mental health services, thus increasing their engagement with those services. Stevens et al. (2022) have offered pilot results to support the role of peer support groups like Kooth in reducing loneliness and increasing perceived social support among young people.

These studies collectively have confirmed that online programs can either have a prevention role, a treatment role, or serve as community-building activities [8] [11].

Potts et al. (2025) have established that the typical length per program is six weeks with a retention rate of 66%, although there is increased engagement with the introduction of human supervision in online programs.

Despite that, this literature review also reveals limitations regarding inclusivity. Most of the individuals who had participated in the studies had been drawn from the university community that had been accessed through convenience sampling. The marginalized sections had remained absent [7].

The underrepresentation of migrants, those in low-income environments, and those with neurodiversity's indicates there is inequality in current literature [7].

In addition, the prominence of anxiety and depression as outcome measures means there is little attention paid to other disorders such as trauma, psychosis, or eating disorders [7].

Female participation stands at approximately 70 percent. This is indicative of gender disproportion in samples [7]. To improve future practices, it is recommended that there be consistency in methodology and protocols to ensure that there is equivalence in the length of programs. The adoption of theories other than CBT is also recommended.

It also stresses the importance of blended learning and a more personalised strategy that involves empathy and compassion-informed practices.

Hunter et al. (2020) emphasize the potential of digital mental health interventions (DMHIs) in addressing the service gap created for marginalized social groups. Thus, with the assistance of mobile applications, internet-based counselling services, and communication platforms utilizing SMS technology, DMHIs can easily meet the limitations associated with the more traditional services [12].

Despite this, health care inequities in technology accessibility reflect — and in some cases worsen — a health care gap (Cook et al., 2016). This is because there had been no real closing

of the gap with regard to mental health care service usage between 2004 and 2012, although there had been a small improvement overall [13]. This is with regard to the races and ethnicities mentioned above, with Whites still exhibiting high usage.

Thus, technological advancement per se does not guarantee equity unless it directly addresses the associated barriers and inequalities inherent in such inequities [13]. As described in the NIH Minority Health and Health Disparities Strategic Plan report (2019-2022) on unlocking mental health equity, technology can be leveraged with the overall strategy of inclusiveness and diversity.

This plan also recognizes the role of culturally appropriate and linguistically competent care in improving minority outcomes [14]. Benavides-Vaello et al. (2013) have especially mentioned the effectiveness of telehealth and mobile health initiatives that have proven to be very helpful in the rural context where transport is a concern.

Their findings indicated that technology could be a possible means to bridge the divides of geography, although it is sustainable depending on the infrastructure and usage informed by culture [15].

Moreover, Unertl et al. (2015) have argued that well-designed online health interventions should be guided by community-based participatory research principles. These principles imply that the duty of developers and health professionals is to join efforts with the community they serve. This means that there could be a combined effort between the methods of informatics and participatory methods to ensure mutual alignment between online health interventions and the needs of communities. These participatory methods appear to support the importance of co-design described in Hunter et al. (2020).

This discussion is continued by Rice et al. (2011) to emphasize that even among the most marginalized sections of society, such as homeless youth, there is continued usage of mobile phones as communication tools.

Their findings suggest that cell phone-based mental health outreach could serve as a convenient entry point for mobile and hard to reach populations [16].

Despite this, Hunter et al. (2020) suggest that availability of technology is not enough. Every community requires solutions that can be contextualized within their sociocultural and linguistic backgrounds.

Collectively, these studies display a crucial insight. This is because digital inclusion is inexorably linked with social justice.

While there is potential for DMHIs to address mental health inequities, their effectiveness is contingent on continued support infrastructure and inter-professional collaboration to ensure they serve the needs of their culturally diverse users [11], [13], [15]- [17].

Thus, innovation in the digital world should not aim at merely digitizing existing systems but think differently through frameworks that consider equity and meet the health objectives for minorities at the national level [14].

Community-Based Participatory Research (CBPR)

Community-Based Participatory Research (CBPR) is a methodology that has evolved with the purpose of reducing the existing gap between scientific discovery and social change. This is because CBPR involves the active participation of communities as equals in the scientific process [18].

Unlike other methods that regard their subjects as passive recipients, CBPR adopts the principles of mutual learning and co-decision-making between the researchers and community members [19].

This participatory model recognizes that sustainable health initiatives can be developed if their roots come from the experiences and culture of the community [18].

As per the report presented by Salimi et al. (2012), one decade of systematic reviews reveal that CBPR not only enhances data validity but also reinforces community faith and ownership in the results.

In addition, Brush et al. (2020) have identified certain key elements for the success of CBPR partnership collaborations for a longer duration. These include communication, sharing of resources, and reflection.

Their critique exemplifies how collaborations formed on a basis of respect and flexibility can sustain their collaborative efforts beyond the completion of one project or one grant [18].

For example, the argument that researcher positionality or the social location of researchers can impact the procedure and outcome of CBPR is supported by Muhammad et al. (2015).

Muhammad et al. (2015) emphasize that self-reflection regarding matters of power and privilege is necessary to ensure that hierarchical patterns are not perpetuated within participatory activities.

Authors Jacquez et al. (2013) have extended the model of CBPR with a discussion of children and adolescents' potential role as active participators rather than just recipients in youth-based studies.

Their results confirm the argument that involving young people in designing, implementing, and evaluating programs for intervention will increase authenticity, creativity, and empowerment [20]. This is because not only does CBPR among young people generate more valid data, it also strengthens young people's participation and leadership [20].

In the context of families and health, Berge et al. (2009) have highlighted how CBPR can be efficiently employed to deal with health disparities through the usage of the existing strengths possessed by families.

Their results emphasize that outcome-based participatory programs implemented among families have been successful in decreasing levels of obesity and health behaviour disparities if families were considered co-researchers instead of subjects [21]. Moreover, the implementation of principles of CBPR among families helps with the translation of scientific knowledge to health strategies [21].

Together, this body of literature indicates that CBPR is more than just a methodological strategy. It is indeed a philosophy of partnership with a focus on democratizing knowledge [18] [22].

Despite this, however, becoming successful at CBPR requires ongoing work to balance power, time, and resource issues to ensure community participation and maintain authenticity [18].

In the end, the approach itself is a transformative bridge between academia and the community — to ensure it is done with communities and not done to them (Muhammad et al., 2015; Berge et al., 2009).

Conclusions

Throughout this body of evidence, technology is highlighted as both an opportunity and a challenge regarding improving mental health equity. The body of evidence surrounding youth

intervention highlights the potential offered through web-based or mobile technology if it is underpinned with a cognitive or mindfulness framework [7] [9].

Rural and minority studies have identified that technology integration can be successfully achieved through investments in infrastructure with culturally responsive alignment [15] [16].

As a means of promoting inclusivity, there is a critical need to engage community-based participatory frameworks like community-based participatory research to co-develop the intervention strategy [17] [18].

Overall, the convergence of online mental health science and participatory inquiry is reflective of the need for innovation to be inclusive and theory guided.

It is only through such a synthesis that digital tools can develop not just technological solutions to problems, but sustainable systems of care for resilience, well-being, and equity within all population [7] [12].

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RISKS AND OPPORTUNITIES ASSOCIATED WITH THE USE OF AI IN EDUCATING CHILDREN

Assist. Prof. Sándor CSIBI Ph.D.¹, Assist. Prof. Monika CSIBI Ph.D.²

¹*George Emil Palade University of Medicine, Pharmacy, Science and Technology;*

²*"Dimitrie Cantemir" University from Târgu Mureș, Faculty of Psychology, Romania*

Corresponding author: Monika Csibi: csibimonika@yahoo.com

Abstract

Recent theoretical advances in modelling the causes and pathways of online use permit an explanation of the phenomenon of normal and excessive AI use. The identification of the risks and benefits of AI-based education, and the necessity of a comprehensive understanding of its characteristics, lead us to analyze the development of disorders. The objective of this study is to examine the concept of AI from the perspective of cognitive functioning, emotional regulation, and behavioural change. The following research questions have guided the present study: 1. The possibilities to address the cognitive impacts of AI use, with a particular focus on perception, attention, memory, language, problem-solving, reasoning, and cognitive load. 2. The exploration of the emotional responses triggered by AI, with a particular focus on emotions such as trust, joy, fear, anxiety, and autonomy. 3. The exploration of the impact of AI integration in educational institutions on student behaviour, social interactions, instances of isolation, and communication styles. 4. The exploration of the psychological effects experienced by students at varying school levels. This study examines a specific group in samples of school-aged children and adolescents using an analytical approach to review reports on AI in education. It analyses published statistics, theoretical perspectives, key findings from scientific forums, and conclusions about harmful AI use. The study also reports on additional mediators, such as value system, anxiety, depression, and risky digital behaviours related to the use of AI. The results and applicability of the study serve to expand knowledge and use the significant potential of AI. The development of AI innovation in education has expanded from laboratory conditions to more complex learning contexts that occur in real life. The purpose of the results is to promote a deeper understanding and awareness of potential risks and useful resources.

Keywords: AI-based education, behavioral change, cognitive impacts, emotional responses, psychological effects

Introduction

Artificial intelligence (AI) is rapidly becoming an integral part of everyday life and is now commonly used in education. However, experts have identified challenges in implementing AI in schools, including misunderstandings about AI's capabilities and the need for AI literacy [1]. Long and Magerko (2020) found that students often misunderstand AI, which makes teaching the subject difficult. For example, children may overestimate AI's abilities and lose interest when their expectations are not met [2]. These misconceptions and biases hinder students' understanding of AI. To address these issues, Tedre et al. (2021) highlighted the use of tools like Google Teachable Machine, which allows students to build machine learning models, and

Scratch, a platform for creating stories, games, and animations [3]. Researchers have examined AI education in schools from three main approaches.

The first approach emphasizes understanding the data used to train AI models, supported by platforms like Machine Learning for Kids, Experiments with Google, and Google Teachable Machine. These allow students to interact with data and see how models are trained [3].

The second perspective suggests building on traditional coding education by teaching students to create models with rule-based commands. Students can use block-based programs such as Scratch and Entry, which provide command blocks for artificial intelligence commands. Students with basic programming skills can use various text-based tools to understand object recognition systems [4, 5].

The third thing to think about is that it is very important to use artificial intelligence in the right way. As AI systems make decisions based on data and algorithms, it is important to think about whether this is fair. Students who understand the ethical issues of AI are better prepared to understand the importance of fair data practices and make moral judgments when using AI [6, 7].

In 2019, research institutions' initiative suggested a document called "Five Big Ideas for Teaching Artificial Intelligence." This framework was used to help create the artificial intelligence education curriculum. The five big ideas concern perception, logic and argumentation, learning, natural interaction, and social impacts. These factors are present in AI education and the adaptation of users to the technical and social aspects of it. Perception regard that the computers use sensors to understand the world around them; logic and argumentation means that persons using AI represent the world and use this representation to reason; learning targets that computers can learn from available data; natural interaction refer to the intelligent agents need knowledge so they can interact naturally with humans; and social impacts means that AI can have good or bad effects on society [8].

Benefits and Innovation-related Aspects of AI Use

Lin et al. (2021) conducted an online survey of 420 elementary school students in Beijing and analyzed the results to examine the motivational factors influencing their interest in artificial intelligence education [9]. The following six motivational factors were identified: (1) intrinsic motivation, (2) career motivation, (3) attention, (4) relevance, (5) self-confidence and (6) satisfaction. The authors concluded that increasing the relevance of AI to students and strengthening their trust in AI could enhance student satisfaction. Innovations in education are of particular importance, given the crucial role that education plays in creating a sustainable future. Innovation has been likened to mutation, the biological process that enables species to evolve and compete for survival (10). Consequently, innovation must be regarded as a vital and constructive agent of transformation. It is an irrefutable fact that any human activity, whether it pertains to industry, business or education, necessitates continuous innovation to ensure its continued sustainability.

The necessity for educational innovation is becoming increasingly urgent. There is a broad consensus that the social and economic well-being of nations is contingent on the calibre of their citizens' education. The advent of the so-named "knowledge-based society," the transformation of information and media, and the escalating specialization of organizations all demand elevated levels of expertise and erudition [11]. Innovation is a process which can be subdivided into three distinct phases: the generation of an idea, the implementation of the idea, and the resultant change which is brought about by the implementation of the idea. Within the

domain of education, innovation can manifest in various forms, including but not limited to novel pedagogical theories, methodological approaches, teaching techniques, educational tools, learning processes, or institutional structures.

The implementation of these innovations can precipitate substantial changes in teaching and learning practices, ultimately culminating in enhanced learning outcomes. The advent of AI technologies has given rise to concerns regarding the potential for these systems to be misused to cause harm. [12] While these harms were once merely speculative, they are now increasingly evident. The employment of drug discovery algorithms has been demonstrated to facilitate the identification of novel toxic substances. Large language models are already being used to design malicious software and automate fraud [13].

The Cognitive and Emotional Effects of the Use of Artificial Intelligence

AI has lots of benefits for schoolchildren, but it can also cause psychological problems. These range from feeling more anxious and lonelier, to problems with identity, getting used to life, problems with what is right and wrong, and feeling overwhelmed. The psychological effects are complicated and occur at different levels of education. Technology is changing the world of education. Teachers, parents and policymakers must work together to see what these changes are and deal with them. By encouraging students to think in a critical way and helping them to understand how to use technology in a healthy way, we can help them deal with the emotional effects of AI use and do well in a world that is becoming more digital. Also, teaching students how to use digital technology responsibly and ethically can help them use AI in the right way. This means that they will be able to enjoy the good things that technology can offer while also protecting their own mental health [14].

Concerning the benefits, in the field of higher education, artificial intelligence (AI) has emerged as a significant tool, offering a range of advantages that can be instrumental in tailoring educational experiences to the specific needs of individual students. AI-based learning platforms utilise data-driven algorithms to assess student performance and tailor content to their individual learning needs [15]. This personalised learning approach has been shown to reduce stress by allowing students to progress at their own pace and receive targeted support [16].

Consequently, this approach has been demonstrated to improve both academic performance and emotional well-being. AI tools provide real-time language translation, assistive technologies for students with disabilities, and 24-hour access to private tutoring and academic support [17]. These tools have been shown to contribute to a more inclusive learning environment, thereby reducing the anxiety and isolation often experienced by students with unique learning challenges [18]. This research line explores the impact of AIED applications (AI education) on various aspects of learning, including academic performance, emotional perception, learning behaviour, and learning ability. A substantial corpus of research has indicated the considerable positive impact of AI technology on students' academic performance. For instance, Wang's (2014) research discovered that assessment-focused e-learning systems effectively enhance student academic performance and rectify misconceptions, particularly among students with limited prior knowledge [19]. Furthermore, students exhibited a favourable attitude towards the integration of AI into education and evinced an increased interest in learning thanks to these applications and improved their ability to concentrate [20].

The field of AI Education research and development draws on a wide array of theories and principles from a variety of disciplines. These theories have their origins in the fields of psychology and education. The development of research in the field of AIED is heavily

informed by theoretical constructs derived from the disciplines of psychology (the application of constructivist learning theory, the theory of learning styles, cognitive theories of learning, the theory of multimedia learning, self-regulated learning, Bloom's Taxonomy of Cognitive Domain, Kolb's experiential learning theory, Learning-by-doing theory, reinforcement learning theory, the theoretical framework of scaffolding, situational learning theory, the theory of cognitive knowledge acquisition, Tinto's theory of student integration, zone of proximal development theory) and education (cognitive load theory, achievement goal theory, activity theory, the theory of flow, metacognition theory, self-determination theory, self-efficacy theory, appraisal theory, the theory of plausible reasoning with regard to human subjects, multiple intelligences theory, social learning theory, sociocultural theory, the investment theory of creativity, the personal construct theory, the schema theory, the systems model of creativity, theory of reasoned action) [21].

The Impact of AI on Social Behaviour

In higher education, AI-based technologies are becoming indispensable tools for students, not only assisting them in their academic activities, but also shaping how they spend their free time [22]. AI has become an integral component of numerous technological applications, including but not limited to AI-based learning platforms, personalised learning assistants and virtual communication tools. It has thus become a vital aspect within students' lives as referenced by Bhutoria (2022) [23].

Students are spending increasing amounts of time in front of screens and relying on artificial intelligence (AI) to complete a variety of tasks, often at the recommendation of their teachers, who encourage them to utilise these technologies for assignments and research purposes [24]. In many cases, students have been observed to turn to AI to find quick answers, automate processes, or personalise their learning experience [25]. Beyond the confines of academia, AI-based tools hold significant prominence in the realm of entertainment. Students engage with these systems during their leisure time to participate in activities such as social media use, gaming, and other digital interactions [26]. Moreover, as research by Nakshine et al. (2022) confirms, excessive screen time can contribute to problems such as digital fatigue, social isolation, anxiety, and poor mental health [27]. It is becoming increasingly evident that students are increasingly dependent on artificial intelligence (AI) for learning, communication, and entertainment. This has resulted in their exposure to a digital environment that may have detrimental consequences for their overall well-being.

The distinction between educational tasks and leisure activities is becoming increasingly indistinct, which poses challenges for students in terms of effective time management and meaningful engagement in offline interactions [28]. Conversely, constant engagement with AI technologies has the potential to hinder students' capacity to establish social relationships, unwind in the absence of digital distractions, or strike a healthy equilibrium between their academic and personal lives [29]. As Cambra-Fierro et al. (2024) observe, in the context of communication, particularly in leisure settings, excessive reliance on AI has the potential to diminish personal social interactions, thereby adversely impacting interpersonal skills and emotional intelligence [30].

It is important to note that students may become more isolated and less adept at real-world social interactions and teamwork, which are critical to their overall social well-being and development. Furthermore, Crawford et al. (2024) report in their study of 387 university students that social support mediates the relationship between loneliness and AI use, suggesting

that AI may increase loneliness if students view it as their primary source of support [31]. As Schepman and Rodway (2023) elucidate, the utilisation of technology devoid of empathy can be regarded as a substandard form of assistance, notwithstanding its capacity to furnish pertinent counsel [32]. These findings were corroborated by identifying a correlation between augmented AI utilization and feelings of loneliness. However, the study did not address the perception of AI as a social support system.

It is evident that students and educators in higher education institutions may experience a sense of inundation in the face of mounting dependence on AI instruments, particularly in instances where they are deficient in the requisite training or technological expertise. This technostress (i.e., the anxiety and discomfort experienced by individuals when interacting with new technologies) has the potential to exert a detrimental effect on both mental health and academic performance [33].

It is imperative for educational institutions to strike a balance between the integration of artificial intelligence and human-centred approaches. While the utilization of AI has the potential to enhance efficiency and personalize learning experiences, an overreliance on technology in this domain may potentially compromise fundamental interpersonal skills and emotional intelligence. As Zhai (2024) suggests, educational approaches should emphasize the need for critical evaluation of AI-generated content, comparing it with knowledge from human sources and recognizing the limitations of AI [34]. Furthermore, emphasis is placed on the necessity of encouraging reflection on the biases inherent in AI outputs. It is proposed that engagement in tasks requiring careful analysis and integration of information from multiple sources can cultivate a more informed and critical utilization of AI tools. Furthermore, it is imperative to prioritize data protection measures to address concerns regarding surveillance [35].

Psychological Effects and Mechanisms During the AI Education and Use

Educational technology companies have introduced a variety of solutions, including adaptive learning systems for personalized instruction, teacher assistance tools for classroom management, and systems for grading, assessment, and second language support [36]. Education is essential for preserving cultural heritage, promoting social progress, and inspiring imagination, making it vital to national and societal development. As educational concepts and methods evolve, they drive social transformation.

Artificial intelligence now influences many industries, accelerating economic and societal growth. Its continued development will further transform social structures, foster harmony between humanity and nature, and present new opportunities and challenges for education [37]. Research on internet addiction has identified five categories based on the types of online services or content involved. Internet gaming addiction is the most prominent, with cases rising due to the unique features of online gaming, drawing significant research attention [38, 39]. Other forms of internet addiction have also been studied. While understanding each subtype is important, recent models explain excessive online use more generally.

General internet addiction (GIA) models clarify why some users develop addictions while most maintain healthy usage. In education, research focuses on learners' cognitive processes, including the development of abilities, skills, and competencies. This also involves improving attitudes, motivation, self-assessment, autonomy, communication, collaboration, and productivity. Sustaining innovation means continuously improving current practices, while

disruptive innovation, such as national reforms, can fundamentally change the educational landscape.

Additional Mediators of AI Use in Children

Most studies of AI in education have looked at it as a technology and focused on learning outcomes, rather than on how students use AI in their everyday lives. Researches provide results which suggest that: a) children understand AI as a technology based on their own experiences; b) children approach AI from a social and cultural perspective, seeing it as a helpful tool; and c) children are very interested in the ethical issues surrounding AI and are keen to understand its social and cultural implications, especially when it comes to AI applications, they are familiar with [40].

Research shows that even before they start learning about AI in school, children start to understand it through what they see in the media or use at home [41]. Some children often use voice assistants like Hey Google or Siri. They also use popular digital platforms like TikTok and YouTube, where algorithms change the online contents, you see based on what you like. Also, children are actively exploring the features of generative AI models such as ChatGPT or DALL-E and using these technologies to write texts and create images. Overall, these interactions help them to understand artificial intelligence better and shape their attitudes towards the technology [42].

Studies show that children don't think of AI as a simple yes or no concept. They see it as a range of different ideas. For example, in a study of 195 Finnish students aged 12–13, Mertala and Fagerlund (2024) showed that students' first ideas about AI are different and often not based on facts [43]. The same findings were reported by the study by Ottenbreit-Leftwich et al. (2022), which looked at what young learners in the United States already know about artificial intelligence and whether they are interested in it. Research shows that students entering the classroom already have a lot of complicated knowledge about AI. Knowing about AI is not a simple yes or no thing. Instead, it includes several of different perceptions, as the results above show [44].

Research also shows that teaching children about different cultures can influence how they think about AI [45], which makes it even more difficult to develop ways to help children understand AI. Studies show that children as young as 7 years old may already experience discrimination. Discrimination can be seen as saying that they are not worthy of being human, which can have a lifelong effect on their mental health. Feeling rejected by their community can make children feel bad about themselves, affect their academic performance, and cause ongoing anxiety. Experiencing discrimination can lead to "stress reactions similar to post-traumatic stress disorder" [46]. Education and parents have been identified as influential factors in children's development. In the event of role models discriminating against children based on their personal or cultural identity, this can have detrimental consequences for the latter.

It is important to note the amplifying effect of human biases through AI, and thus the discrimination manifested in interactions between children and AI would also have significant mental health implications [47].

Discussion

The integration of educational technology in conventional learning environments, characterized by the utilization of overhead projectors, videos, or iPads, can be regarded as a form of evolutionary and sustainable innovation. The explanation of it is that merely introduces incremental modifications to the prevailing learning paradigm. The integration of educational technology in conventional classrooms, through the utilization of overhead projectors, videos, or iPads, can be regarded as evolutionary, sustainable innovation insofar as it merely introduces incremental modifications to the learning process [48]. This assertion is equally applicable to the domain of online learning, as it engenders systemic transformation, profoundly impacting the very structure, form, and methodologies employed in teaching and learning. The divergence between the public's expectations regarding the efficacy of educational technology (ET) and its real-world applications in educational settings can be ascribed to educators' perceptions of technology.

Researchers have shown that the written works of educational researchers about technology can help to understand the main issue [49]. It is important to understand how students learn when they use technology on their own, like laptops or phones. We also need to explain how we can predict how electronic devices might change students' thinking, the way they learn, their behaviour, and their relationships with other people, and can be good for students and teachers to talk to each other in person.

Students learn best from real-life examples and practical experiences, and teachers really appreciate this approach [50]. Many people overestimate how good technology is. This can have a negative impact on online education and learning. It also does not think about how important it is to have good teaching methods and for teachers to have the right training. It can also have a very negative impact on our social lives, on our ability to work together, and on our ability to survive. These has also changed the way education is taught. The impact of technology on students' attention and memory has been a subject of much debate, with opinions divided on its beneficial or detrimental effects. It is imperative to issue a serious warning about the potential negative consequences of unregulated internet usage, particularly in the context of academic performance.

The impact of modern media, particularly networked computers, on cognitive abilities such as thinking skills, memory, and the capacity for concentration on reading and writing has been a subject of considerable debate. Some researchers have suggested that these technologies may also have a detrimental effect on creativity [51]. The utilization of generative artificial intelligence has been demonstrated to facilitate the creation of context-embedded and personalized learning materials and resources, thereby contributing to an enhancement in the learning experience. A body of research has been conducted that utilizes qualitative studies to analyze the level of complexity of practical cases generated by generative artificial intelligence for case-based learning [52].

The findings of this research demonstrate that the utilisation of AI facilitates the generation of highly complex cases and their adaptation to requirements in terms of analytical, conceptual, and information presentation dimensions. However, it is important to note that human intervention is essential to improve the coherence, consistency, accuracy, and relevance of the tools. The significance of educators and education professionals in the development and application of artificial intelligence is emphasised by the recognition of their integral role in this process. Furthermore, the potential of artificial intelligence as a complement to the creation of educational resources is highlighted.

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ORTHOREXIA AS EXCESSIVE ATTENTION TO A HEALTHY DIET

Dr. Elżbieta OLCZAK, Dr. Joanna RASŁAWSKA-SOCHA

Uczelnia Społeczno-Medyczna w Warszawie, Wydział Nauk Medycznych i Nauk o Zdrowiu, Warszawa, Polonia
Correspondent: Elżbieta Olczak, Joanna Raslawski-Socha: elaolczak@gmail.com

Abstract

The aim of this study was to determine the prevalence of orthorexia in the study group of students. The survey was conducted among students of the USM in Warsaw and the PUM in Szczecin via social media. The Bratman and Knight questionnaire was used, with respondents able to answer yes or no, with at least four of the 10 questions being positive. No differences were found between USM and PUM students among the dietetics, cosmetology, and dentistry students. 60% of respondents planned their meals the day before. 52% of respondents indicated that what they ate was important. 57% of respondents indicated that they were willing to sacrifice the pleasure of eating to maintain a healthy diet. 73% of respondents indicated that their self-esteem increased when they ate healthily. 50% of respondents felt guilty when they broke restrictions. 60% of respondents had a normal BMI. A significant prevalence of orthorexia was found among women. Research findings indicate a significant prevalence of orthorexia among students.

Keywords: *orthorexia, BMI, women*

Introduction

Excessive consumption of high-calorie foods and unhealthy eating habits, such as unnecessary dietary restrictions and overeating, have become a serious public health problem worldwide [1]. Orthorexia was originally coined by American physician Steven Bratman in 1997 as a pathological obsession with eating pure, healthy, or clean foods. Currently, orthorexia is not included as a formal diagnosis in the latest version of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5). However, clinical observations suggest that orthorexia may differ from other eating disorders such as ARFID (avoidant/restrictive food intake disorder), BED (binge eating disorder), BN (bulimia nervosa), or AN (anorexia nervosa). As an eating pattern, orthorexia differs from restrictive and emotional eating. People with orthorexic tendencies focus on food quality, avoid foods they consider unhealthy or impure, and spend a lot of time thinking about food purchases. The consequences can lead to malnutrition and affect personal relationships with others [2].

The AI-generated responses point out that "orthorexia manifests itself as an obsessive focus on eating only 'healthy' foods, which can lead to malnutrition and social isolation. This overemphasis on health and food quality control, coupled with an excessive focus on healthy *So, Margo. Terminator coloring among* eating is an increasingly common disorder. Orthorexia (or orthorexia nervosa) is an eating disorder characterized by an obsessive focus on the quality of food consumed rather than its quantity. Often, entire food groups perceived as "unhealthy"

are eliminated, e.g., sugars, fats, preservatives. Another feature is feeling intense anxiety or shame when breaking one's own strict dietary rules. Social isolation may occur, manifested by avoiding meals outside the home or social situations where "safe" food is not available. Weight loss may accompany this, although weight loss is not the main goal; a restrictive diet can lead to nutritional deficiencies and even health problems" [AI: Orthorexia: obsession with healthy eating].

The impact of artificial intelligence on orthorexia is complex and twofold. Potential risks associated with AI: AI algorithms personalize content, which can lead to the creation of "information bubbles" around extreme dietary trends. Users who are initially interested in healthy eating may be inundated with content promoting increasingly restrictive diets, which can contribute to the development of depression. [AI: Orthorexia: obsession with healthy eating].

Some apps that use AI to analyze meals and track calories, while helpful for many, can reinforce compulsive behaviours and the need for constant control over food in susceptible individuals. Artificial intelligence can help in the early detection of orthorexia by analyzing online behaviour, entries in diet apps, and social media content, identifying patterns that indicate the disorder. [AI: Orthorexia: the obsession with healthy eating].

AI systems can provide personalized, reliable information about nutrition, helping to distinguish healthy habits from obsessive beliefs, which is crucial in prevention. It is essential that AI tools are designed and used with caution and ethics, and that their results are verified by qualified medical professionals. [AI-generated responses may contain errors].

Materials and Methods

The research group consisted of 201 students from the University of Social Sciences and Medicine in Warsaw and the Pomeranian Medical University in Szczecin, who were asked 10 questions. The respondents gave their informed and voluntary consent to participate in the survey. Questions concerning orthorexia, according to Bratman and Knight, were used.

The respondents answered the following 10 questions [3]:

1. Do you spend more than 3 hours a day thinking about healthy eating?
2. Do you plan your meals the day before?
3. What is more important to you: what do you eat or the pleasure you get from eating?
4. Has your quality of life decreased since adopting a healthy diet?
5. Are you becoming more restrictive in your dietary restrictions?
6. Are you able to sacrifice the pleasure of eating to maintain a healthy diet?
7. Does your self-esteem increase when you eat healthily?
8. Do you feel guilty when you break your restrictions?
9. Do you think your diet has had a negative impact on your social interactions?
10. Do you feel that you are in complete control of your life when you eat properly? [3].

The questionnaire also included questions about age, gender, height, and weight. BMI was calculated based on height and weight. Based on the data obtained, the study participants were divided into the following groups: < 18.50 underweight, 18.50–24.99 normal weight, 25.00–29.99 overweight, ≥ 30.00 obese. The study group consisted of 201 people. Age groups were identified during the study.

Results

201 students from two different universities studying full-time and part-time in Poland voluntarily participated in the study. Among the respondents, 22% were aged 18–21, 27% were aged 22–25, 12% were aged 26–29, and 13% were aged 40–43. The survey was completed by 87% women and 13% men. 80% of respondents live in cities and 20% live in rural areas. The results of the responses to the questions according to the Bratman and Knight questionnaire, in which respondents could answer "yes" or "no," are presented in Table 1.

Table 1. Results of a survey conducted on students.

Questions	Yes [%]	No [%]
1. Do thoughts about your diet occupy more than 3 hours of your day?	18	82
2. Do you plan your meals the day before?	60	40
3. What is more important to you: what do you eat or the pleasure you get from eating?	57	43
4. Has your quality of life decreased since adopting a healthy diet?	10	90
5. Are you becoming more restrictive in your dietary restrictions?	37	63
6. Are you able to sacrifice the pleasure of eating to maintain a healthy diet?	59	41
7. Does your self-esteem increase when you eat healthily?	74	26
8. Do you feel guilty when you break your restrictions?	51	49
9. Do you think your diet has had a negative impact on your social life?	12	88
10. Do you feel that you are in complete control of your life when you eat properly?	33	67

Source: own research.

Surveys of 201 respondents indicate that 82% of respondents do not spend more than 3 hours a day thinking about a healthy diet (Table 1). In studies [4], participants with a moderate orthorexic eating behavior profile showed higher levels of disturbed eating attitudes and behaviours, while those with a low orthorexic eating behaviours profile showed higher levels of intuitive eating.

59% of respondents plan their meals the day before (Table 1). The results (Barlow et al., 2024) confirm perfectionism and health anxiety as risk factors, as well as the acceptance of mindfulness as a preventive factor in both orthorexia nervosa and healthy orthorexia [5].

In the study, 57% of respondents say that what they eat is more important to them (tab 1).

Eating tasty foods, even when no additional energy is needed, indicates that eating is satisfying [1].

90% of respondents said that their quality of life did not deteriorate after introducing a healthy diet (tab 1).

In a healthy population, it has been found that appetite is suppressed after meals because satiety signals after a meal alter the secretion of intestinal hormones and stomach stretch signals. Nutrients entering the intestines affect brain activity through the brain-gut axis, resulting in a feeling of fullness. The desire to eat makes food appetizing, which leads to the desire and consumption of food [1]

63% of respondents said they do not follow any major dietary restrictions (Table 1).

The relationship between orthorexic eating behaviors and intuitive eating is noteworthy, where intuitive eating refers to an internal eating style driven by physiological cues rather than external emotional and situational cues [4].

Abnormal addictive behaviors toward food in patients with eating disorders are associated with reward circuits that are also responsible for substance and non-substance addictions [1].

59% of respondents say they are willing to sacrifice the pleasure of eating in order to maintain a healthy diet (tab 1). 74% of respondents say their self-esteem increases when they eat healthily (tab 1).

When we eat something very tasty, we feel good and create a memory that helps us remember the circumstances in which we ate it. This memory reminds us to repeat the same behaviour next time. Similarly, if we eat something that helps reduce our sadness or anxiety, we may remember to eat certain foods to reduce specific emotional states [7].

50% of respondents say they feel guilty when they break the restrictions (tab 1). 88% of respondents said that the diet did not have a negative impact on their social interactions (tab 1). 67% of respondents say they do not feel in full control of their lives when they eat properly (Table 1).

The results of the study (Plichta et al., 2020) indicated a positive correlation between orthorexic behaviours and the importance of food choice motives such as health, natural content, and weight control.

The relationships between the assessed food choice motives and orthorexic behaviours measured using ORTO-15 and ORTO-7 were similar. Therefore, the results confirm the assumption that orthorexic behaviours are associated with higher health motivation scores and cause an increase in psychosocial disorders. Health motivation primarily concerns healthy orthorexia, while psychosocial disorders concern orthorexia nervosa. Orthorexic behaviours may indicate both healthy orthorexia and pathological traits [6].

Eating behaviours are not passively dependent on energy requirements and hormonal changes. We modify our behaviour to achieve a specific goal, and cognitive modulation makes it more flexible. Thus, cognitive impairments, such as deficits in inhibitory functions, lead to abnormal eating behaviours, such as overeating and food avoidance [1].

The BMI of the respondents was calculated based on the height and weight values provided in the survey. After calculation, the results showed that 65% of respondents had a normal body weight, 20% were overweight, 7% were obese, and 8% were underweight (Table 1). Higher scores for orthorexic behaviours were associated with lower BMI, which was true for both men and women [2].

The same questions were also asked in AI mode, and the following answers were obtained:

AI response to the question: Do you spend more than 3 hours a day thinking about your diet? My thoughts are not occupied with counting calories at all, because I am an AI assistant, not a person, I do not eat or need a diet. I was designed to process information and help users, not to worry about meals.

To the question: Do you plan your meals a day in advance? AI replied: As an AI assistant, I don't eat meals in the human sense, but I can help you plan your meals. I can generate meal ideas, create shopping lists, and arrange weekly meal plans.

When asked: What is more important to you: what you eat or the pleasure you get from eating? The AI replied: Nutritional value (what you eat) is crucial for survival, physical health, energy, and disease prevention. Providing the body with the right nutrients is fundamental to its functioning. The pleasure of eating is an important part of quality of life, culture, social relationships, and mental health; food is also about emotions, traditions, and comfort. The optimal approach is often to find a balance between these two aspects: choosing a diet that also provides pleasure. One does not have to exclude the other.

To the question: Has your quality of life decreased since adopting a healthy diet? The AI responded: My existence is a computer program, not a human being, so the concept of "quality of life" as it relates to humans does not apply to me. I do not experience the pleasure of taste, hunger, or the physical benefits of healthy eating. I operate based on algorithmic data. My "mode of operation" does not change due to diet but only based on software updates and access to information. I do not eat, so my "quality of life" cannot decrease or improve because of this.

To the question: Are you becoming more restrictive in your dietary restrictions? AI replied: No, I am not. I am an AI language model, not a person, so I have no body, I do not eat food, and I have no personal dietary restrictions. My answers about diets are based on analyzing and synthesizing information from the internet and databases, providing objective and fact-based data on various approaches to nutrition, health recommendations, and diet plans. I can help you find information on: different diets, nutritional values, recipes, health recommendations. My approach to diets is neither restrictive nor permissive; it is informative and neutral.

To the question: Are you willing to sacrifice the pleasure of eating in order to maintain a healthy diet? AI replied: The modern approach to healthy eating rarely requires a complete sacrifice of pleasure. Instead, the emphasis is on balance and moderation: you can enjoy your favourite, less nutritious foods from time to time, as long as your diet is based on healthy and nutritious foods. Discovering new flavours: A healthy diet is extremely varied and allows you to discover delicious foods that are also good for your body. Vegetables, fruits, whole grains, proteins, and fats can be prepared in ways that provide culinary satisfaction. Mindful eating: Focusing on your meal and appreciating each bite can increase your enjoyment, whether it's a salad or a piece of cake. For many people, maintaining a healthy diet becomes a pleasure in itself, as it is associated with feeling better, having more energy, and feeling satisfied with taking care of their body.

To the question: Does your self-esteem increase when you eat healthy? AI replied: As an AI language model, I have no body, emotions, or personal feelings, so the concept of "self-esteem" in the human sense does not apply. I do not experience satisfaction from eating or pride in following a diet. My "functioning" consists of processing information and generating responses based on the data I have been trained on. I can tell you what psychology and scientific research say about the relationship between healthy eating and self-esteem in humans. Positive impact on well-being: Many people report that healthy eating improves their mood, energy levels, and overall well-being. Sense of control: Consciously taking care of your diet can give you a sense of control over your life and health, which often translates into increased self-confidence. Achieving goals: Achieving goals related to, for example, weight loss, is a source of pride and reinforces a positive self-image. So, although I don't experience it myself, for some people this connection is very real and positive.

To the question: Do you feel guilty when you break the restrictions? The AI replied: Feeling emotions such as guilt is a human trait. As an artificial intelligence, I have no consciousness or ability to feel emotions, including guilt, satisfaction, or regret. My actions are based on following the rules and guidelines that have been programmed into me.

To the question: Do you think your diet has negatively affected your social interactions? The AI replied: My diet has no effect on my social interactions because I do not eat. I am an AI language model created by Google, not a person who consumes food. I do not experience human interaction, social meals, or any other social situations where diet might be relevant.

To the question: Do you feel that you are in complete control of your life when you eat right? AI responded: Eating the right things can greatly enhance your sense of control over your life because it is a specific, daily area that you can consciously manage. Making healthy food

choices requires self-control and planning, which directly translates into a sense of agency and self-confidence. This link between diet and mental well-being is well documented in research.

Conclusions

Most respondents plan their meals a day in advance, and most of them say that they do not follow more restrictive diets. Their self-esteem increases when they eat healthily. The diet used by the respondents did not negatively affect their social interactions. There is a significant prevalence of orthorexia among women as well as a significant prevalence of orthorexia among students. The questions generated for artificial intelligence (AI), which were previously asked to survey participants, were descriptive answers.

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CLASSROOM DIVERSITY AS THE FOUNDATION OF INCLUSION

Prof. univ. Elena-Adriana TOMULETIU, PhD.

*“Dimitrie Cantemir” University of Târgu Mureș, Faculty of Psychology, Romania
Correspondent: Elena-Adriana Tomuletiu*

Abstract

The article “Classroom Diversity as the Foundation of Inclusion” highlights the essential role of the teacher in creating an equitable, open, and responsive educational environment tailored to each student’s needs. In a society marked by social, cultural, religious, and identity pluralism, the school becomes the space where differences must be understood, respected, and valued as learning resources rather than sources of exclusion. The paper emphasizes the transition from integration to inclusion, underlining the teachers’ mission — especially that of support teachers - to ensure equal access to education for all students, regardless of social status, ethnicity, religion, gender, sexual orientation, or neuropsychological development. Diversity is analyzed through multiple dimensions: social (economic inequalities), ethnic (integration of minorities), religious (interfaith respect), gender (combating stereotypes), and physical or cognitive (supporting students with special educational needs). Intercultural education and inclusive education are presented as complementary responses to diversity, providing strategies to transform it into an opportunity for growth. Intercultural education goes beyond mere tolerance of differences, promoting dialogue, cooperation, and solidarity. By fostering empathy, mutual respect, and critical thinking, it contributes to building a school community founded on equity and understanding. In turn, inclusive education addresses individual diversity by adapting the school to students’ needs rather than the other way around. It relies on principles such as valuing uniqueness, family involvement, interdisciplinary collaboration, and ensuring curricular and physical accessibility. In conclusion, the article argues that diversity is not a challenge but a vital resource for modern education. Through intercultural and inclusive education, the school becomes a space of respect, equity, and dignity - a school for all and for each individual.

Keywords: education, diversity, interculturality, inclusion, equality

1. Cosa Intendiamo per Diversità?

La psicopedagogia tende sempre più ad affrontare il tema della diversità specifica dei gruppi educativi, come base per conoscere gli elementi più profondi che coesistono all'interno del gruppo, dall'individualità di ciascun membro alla diversità che essi manifestano, al fine di trovare i metodi più efficaci per sviluppare un clima educativo positivo basato sul diritto alla differenza, sul rispetto reciproco e sulla comunicazione interculturale.

Ogni individuo o membro di un gruppo è unico nella sua struttura bio-psico-sociale; ogni membro ha e manifesta il suo diritto di essere diverso, che è determinato dalla sua unicità, dalla sua identità. Ma, non di rado, è proprio la differenza a creare problemi al diverso nell'integrarsi nel gruppo o nell'essere accettato dal gruppo, cioè dall'altro, dall'alterità.

Il problema della diversità è più sentito in tutta l'umanità. L'apertura delle barriere culturali, i continui scambi culturali, l'emigrazione di massa, le nuove tecnologie di comunicazione hanno portato, in un tempo relativamente breve, all'affermazione di una diversità di modi di vita nella stessa società. I membri di queste società vogliono e hanno il diritto di vivere, senza disturbare gli altri, in modi diversi, seguendo i propri modelli culturali. Così, il pluralismo e l'incompatibilità dei valori sono diventati una condizione della realtà sociale. La coesistenza di modi di vita diversi si basa sull'idea che esistano diversi modi di vita vantaggiosi per le persone, proprio perché nessuno di essi è il migliore per tutti. Ma non di rado la realtà ha rivelato una serie di conflitti intergruppi, interetnici e persino familiari, che sono il risultato di una mancanza di comprensione e di accettazione delle differenze.

Questa realtà della diversità risuona fortemente in tutti gli ambienti sociali, culturali, educativi e persino economici. Tuttavia, la questione di come affrontare la diversità, comprenderla e rispettarla, deve essere appresa e praticata nella vita quotidiana. Nonostante questi imperativi, l'educazione rimane ancora un lavoro di conformismo, di controllo sociale. "È indiscutibile che la scuola faccia delle scelte, ma la sua scelta fondamentale è innanzitutto quella della non pluralità" [1].

Anche i gruppi educativi, e ci riferiamo in particolare ai gruppi scolastici, si trovano sotto questo "impero" della diversità, che a volte è difficile da gestire. Anche se la diversità è spesso espressa in termini di cultura, in termini di gruppi e di relazioni tra di essi, è la differenza che porta alla diversità. In termini di classe, le differenze tra gli alunni possono essere prioritarie, dal rendimento scolastico allo status sociale (ereditato), e la questione più importante è come gestirle. Queste differenze creano modi diversi di essere percepiti dagli altri, ma anche modi diversi di percepire gli altri, con ampie implicazioni per le relazioni di gruppo, sia tra insegnanti e alunni, sia tra alunno e alunno, sia tra alunno e insegnante, sia tra alunno e alunno. Pertanto, le principali variabili prese in considerazione per classificare le differenze coesistenti nel piccolo gruppo educativo sono: l'appartenenza degli alunni a un gruppo particolare (differenza di classe sociale, razza, genere degli alunni, appartenenza religiosa), le caratteristiche individuali degli alunni e le aspettative degli insegnanti [2].

Ogni alunno arriva nella sua classe con determinanti psicologiche, sociali o culturali che lo rendono diverso dagli altri membri del gruppo e che possono ostacolare o favorire la sua integrazione, interrelazione, accettazione.

2. Caratteristiche della Diversità di Classe

2.1 Diversità Sociale

Spesso la differenza di classe sociale, tradotta anche dallo status socio-economico della famiglia, porta a classificare gli alunni in due grandi categorie estreme: alunni poveri e alunni ricchi. Questo dà origine a un pregiudizio iniziale: i bambini poveri sono quelli che non hanno le opportunità materiali, culturali, educative e familiari che favoriscono il loro successo; i bambini ricchi, quelli per cui la famiglia fornisce tutte le condizioni materiali ed educative, sono quelli che raggiungeranno il successo. In effetti, molti studi hanno dimostrato che il background degli alunni è anche un fattore di successo scolastico, oltre al fatto che la povertà è una delle principali cause di abbandono scolastico e di mancata iscrizione. Secondo l'Istituto di Statistica dell'UNESCO, nel 2020 più di 64 milioni di alunni della scuola primaria abbandoneranno la scuola, e i tassi di abbandono sono ancora più diffusi nei Paesi a basso e medio reddito [3]. Secondo lo stesso studio, tra le cause principali dell'abbandono scolastico vi sono: il lavoro

minorile (un bambino su dieci in tutto il mondo è vittima del lavoro minorile) e il matrimonio (anche se il matrimonio sotto l'età legale di 18 anni è una violazione dei diritti umani, quasi quattro ragazze adolescenti su dieci si sposano prima dei 18 anni nei Paesi poveri). In tutta Europa, un quindicenne su cinque (20%) è colpito da povertà educativa e più di un bambino su cinque (28%) è a rischio di povertà o esclusione sociale [4].

È stato anche dimostrato che è la scuola, attraverso l'atteggiamento dell'insegnante e del gruppo, a creare differenze e quindi a ostacolare il successo. Anche all'interno di una classe, si può osservare in alcuni casi che, quando si organizzano gli alunni in sottogruppi, il fattore "appartenenza alla classe" fa sentire la sua presenza: gli "alunni ricchi" appartengono al "gruppo buono", gli "alunni poveri" al "gruppo povero". Questa differenza ne determina un'altra, ossia la collocazione degli insegnanti che insegneranno alle classi in questione: gli insegnanti "bravi" saranno collocati nella prima categoria, quelli "meno bravi" nella seconda. Infine, questa forma di discriminazione ha anche altre conseguenze: è stato riscontrato che gli insegnanti che lavorano con le cosiddette "classi buone" sono più pazienti, tolleranti, più vicini agli alunni e moderni nel loro modo di pensare, lodano e incoraggiano gli alunni, utilizzano una metodologia formativa, mentre gli insegnanti che lavorano con le "classi deboli" sono tradizionalisti, insoddisfatti degli alunni, autoritari, diffidenti nei confronti delle capacità degli alunni, critici, tendono a punire frequentemente [2].

2.2 Diversità Etnica

La razza o l'etnia è un altro fattore determinante delle differenze tra i gruppi di classe. Diversi studi e ricerche sul rapporto tra discriminazione etnica e razziale nelle scuole e atteggiamenti verso la scuola hanno rilevato che gli studenti che riportano casi di discriminazione etnica o razziale hanno maggiori probabilità di abbandonare la scuola rispetto ai loro coetanei che non vivono tali situazioni [5,6,7].

La discriminazione sulla base della razza e dell'etnia sta emergendo nelle scuole europee come una barriera persistente all'inclusione. In generale, la ricerca indica che la discriminazione si manifesta a livello istituzionale - attraverso la segregazione, le pratiche di classificazione e le politiche di ammissione - e interpersonale, con comportamenti di compagni e insegnanti che rafforzano l'esclusione [8]. Ci sono anche studi che evidenziano modesti miglioramenti negli atteggiamenti interetnici nel corso del tempo, ma l'evidenza prevalente espone un modello multiforme di discriminazione nel panorama educativo europeo.

Nel contesto dell'Europa centrale, la discriminazione etnica colpisce in particolare i bambini della minoranza Rom, che sono sottoposti a pratiche vietate dalla legge antidiscriminazione e che ostacolano l'integrazione. Ad esempio, alcuni studi rivelano che i processi di omogeneizzazione etnica sono comuni nelle scuole della Repubblica Ceca, della Polonia e della Slovacchia [9]. Altri studi mostrano che gli alunni rom devono affrontare pregiudizi sia da parte dei compagni che degli insegnanti [10]. Studi condotti in Ungheria rivelano che gli alunni rom ricevono voti più bassi indipendentemente dai risultati dei test [11].

In Romania, ad esempio, le scuole segregate sono passate dal 12% del 1998 al 20% del 2016 [12]. Rispetto ad altre etnie, il rischio di abbandono scolastico per i bambini rom è sei volte più alto e la percezione della scuola come un ambiente ostile o poco familiare è l'indicatore più forte che spiega l'abbandono, secondo lo studio "Early school leaving - causes and effects" del Roma Education Fund Romania [13]. In pratica, un alunno rom su tre ha abbandonato la scuola, e tra gli alunni non rom circa uno su 14, cioè il 7%, mentre la quota della stessa categoria tra gli alunni rom è del 31%. Da un altro punto di vista, oltre l'80% degli abbandoni scolastici è

costituito da alunni rom: "Calcolando l'odds ratio si conclude che se sei un bambino rom hai sei volte più probabilità di abbandonare la scuola rispetto a un bambino non rom", secondo lo studio [14]. La sfiducia dei genitori nella scuola, nella sua utilità, persiste ancora, soprattutto perché l'istruzione nelle scuole delle comunità rom, per lo più in periferia, è di livello inferiore. Condizionare l'aumento dell'indennità alla frequenza scolastica ha portato a un certo aumento delle iscrizioni dei bambini rom, soprattutto alla scuola primaria.

Sono stati sviluppati e attuati centinaia di progetti su questo tema, sono stati adottati vari metodi per combattere l'intolleranza che si respira in ambito scolastico nei confronti della popolazione rom. Tuttavia, il fenomeno della discriminazione esiste e si manifesta nella pratica educativa quotidiana, sia da parte degli insegnanti che degli alunni. Si tenta di "eliminarli" da alcune classi scolastiche e, laddove "sopravvivono", "beneficiano" di un atteggiamento ostile, di emarginazione e di rifiuto da parte degli insegnanti. Inoltre, nella pratica educativa attuale, sono poco richiesti, raramente elogiati e costantemente criticati. Inoltre, "godono" degli stessi atteggiamenti da parte dei loro compagni e continuano a essere rifiutati come "compagni di banco" o "compagni di apprendimento". Il problema è molto più ampio. Questo atteggiamento discriminatorio è il risultato di tutta una "storia" di ripetuti rifiuti ed emarginazione, ma anche di una mancanza di effetti positivi laddove si è cercato e investito per imparare a "vivere meglio insieme". Ci sono state anche una serie di misure volte alla discriminazione positiva: l'introduzione di corsi di lingua rom, posti speciali nelle scuole superiori e negli istituti, la nomina di ispettori rom in tutti gli ispettorati scolastici, corsi per cambiare l'atteggiamento degli insegnanti verso i diritti dei bambini rom. Tuttavia, il numero di analfabeti rimane elevato, così come il tasso di abbandono scolastico tra gli alunni rom.

2.3 Diversità Religiosa

Le classi con studenti di fedi diverse riflettono la realtà multiculturale e globalizzata del mondo di oggi. Questo ambiente può essere un'opportunità per imparare il rispetto reciproco, l'empatia e la coesistenza pacifica. Gli alunni possono beneficiare di attività che incoraggiano la conoscenza delle diverse tradizioni religiose, promuovendo così l'apertura culturale e riducendo gli stereotipi.

La maggior parte delle religioni sottolinea valori come il rispetto, la compassione, la responsabilità e la giustizia. Questi valori possono diventare un punto comune che unisce gli alunni, indipendentemente dalle differenze di fede. Un approccio laico a questi valori può contribuire a creare un'atmosfera positiva in classe.

Ecco alcuni esempi di diversità religiosa:

- In una classe possono essere rappresentate le principali religioni come il cristianesimo (ortodosso, cattolico, protestante), l'islam, l'ebraismo, l'induismo o il buddismo, ma anche denominazioni o gruppi spirituali meno noti.
- Ci possono essere anche studenti che non praticano una religione, e questa è un'opportunità per imparare la libertà di scelta e l'importanza del rispetto delle prospettive personali.

Le diverse festività religiose, come Natale, Ramadan, Hanukkah o Diwali, possono essere integrate nelle attività didattiche per promuovere la comprensione reciproca. Inoltre, l'organizzazione di attività a tema può creare un senso di appartenenza per tutti gli alunni e incoraggiare il dialogo culturale.

Quali sfide potremmo affrontare?

Gli insegnanti devono fare attenzione a non favorire alcuna religione in particolare ed evitare qualsiasi forma di discriminazione o esclusione.

Creare uno spazio aperto per le discussioni sulla religione deve essere fatto con rispetto e sensibilità, in modo da non violare le convinzioni personali degli studenti.

L'insegnante può facilitare le discussioni sulla storia e sulla cultura delle diverse religioni senza imporre il proprio credo religioso. Questo aiuta gli alunni a comprendere la diversità religiosa come parte integrante della società.

La diversità religiosa in classe è quindi un'opportunità preziosa per coltivare l'empatia, il dialogo e il rispetto. Gli insegnanti possono svolgere un ruolo chiave nel rendere questa diversità un punto di forza del processo educativo, promuovendo un ambiente inclusivo e armonioso.

2.4 Diversità di Genere e Identità Sessuale

La ricerca sul curriculum scolastico nascosto negli ultimi anni si è concentrata sulle differenze di genere nella scolarizzazione. Queste ruotano intorno alla questione delle donne (studentesse) nell'istruzione scolastica, con un'attenzione particolare all'accesso, alla natura e alla forma della partecipazione e all'impatto o ai benefici a breve o lungo termine. È emerso che le differenze di genere che si creano sono legate sia all'organizzazione delle istituzioni scolastiche nel loro complesso sia alle relazioni tra insegnanti e alunni all'interno della classe.

L'impatto dell'istruzione sulle ragazze è diverso da quello sui ragazzi, sia per quanto riguarda alcuni risultati immediati come l'immagine di sé, la motivazione, il rendimento, sia per quanto riguarda gli effetti a lungo termine come l'acquisizione di un lavoro o il livello di retribuzione.

L'organizzazione della scuola e della classe, le relazioni sociali in classe e il curriculum nascosto sono stati i temi oggetto di ricerca che hanno offerto varianti esplicative a questo proposito [15]:

- sono state rivelate molte forme di sessismo linguistico (cioè l'eccessiva mascolinizzazione dei termini);
- le attività scolastiche e i giochi didattici in classe e a scuola si basano su una divisione sessuale del lavoro (ruoli/compiti per le ragazze, ruoli/compiti per i ragazzi), questi fattori interagiscono con le aspettative differenziate degli alunni sulla loro futura posizione nella società e con la pressione del gruppo di età, che di fatto riflettono anche la posizione delle donne in quella società.

Fin dalle prime classi (6-7 anni), il genere degli alunni è un fattore molto importante per l'insegnante [16]:

- I buoni risultati di una ragazza sono visti più come l'effetto di uno sforzo molto intenso e del conformismo che come espressione delle sue capacità e competenze e non sono valutati allo stesso modo dei ragazzi;
- Le ragazze sono più dipendenti, obbedienti e subordinate, mentre i ragazzi sono più aggressivi, indipendenti e difficili da controllare;
- I ragazzi sono più creativi, originali e indipendenti;
- Le ragazze ottengono risultati migliori nell'apprendimento, ma gli insegnanti ritengono che ciò sia dovuto al fatto che le ragazze si conformano maggiormente alle aspettative istituzionali;

- Il comportamento attivo e sfrenato di un ragazzo viene etichettato come "corretto", aggressivo, assertivo o avventuroso, mentre le ragazze che si comportano nello stesso modo sono considerate sciocche, viziate, confuse, esagerate, pazze.

Infine, nei manuali scolastici e nei materiali didattici compaiono più personaggi maschili che femminili: i personaggi maschili sono rappresentati come attivi e dominanti, mentre quelli femminili come passivi e dominati, il che si riflette anche nella presentazione della famiglia. I manuali ispirano l'idea che le donne siano adatte solo a certi tipi di lavoro, generalmente quello domestico. La natura "ideologica" dei libri di testo scolastici è un punto di partenza sia per indagare il nodo centrale delle rappresentazioni sociali, sia per studiare l'impatto di tale letteratura sui risultati delle ragazze e dei ragazzi e sull'immagine di sé [17].

Analizzando la situazione delle persone LGBT a scuola, secondo un sondaggio condotto tra le persone LGBT dall'Agenzia dell'Unione Europea per i Diritti Fondamentali nel 2013, otto intervistati su dieci in ciascuno Stato membro dell'UE hanno assistito a commenti o azioni negative a scuola perché un compagno era percepito come LGBT. Almeno cinque persone LGBT su dieci nell'UE hanno nascosto il proprio orientamento sessuale o identità di genere quando frequentavano la scuola prima dei 18 anni. Una persona LGBT su cinque che ha frequentato la scuola o l'università, o i cui figli hanno frequentato la scuola o l'università nell'ultimo anno, si è sentita discriminata perché LGBT.

Le molestie basate su atteggiamenti omofobici sono comuni negli ambienti educativi in Europa e, secondo il Rapporto europeo sull'omofobia, le autorità scolastiche in Europa non prendono molto sul serio il bullismo LGBT e gli insegnanti non hanno strumenti o incentivi sufficienti per affrontare il problema [18].

Uno studio pubblicato dalla ONG britannica Stonewall, ad esempio, mostra il risultato sorprendente che tre studenti gay su cinque che subiscono bullismo omofobico affermano che gli insegnanti che assistono alle prepotenze non intervengono mai. Solo la metà degli studenti gay afferma che le loro scuole condannano il bullismo omofobico. Lo stesso rapporto mostra che il bullismo può indurre gli studenti a modificare i loro piani educativi e può anche avere un impatto diretto sul lavoro scolastico, nonché una preoccupazione per la migrazione - il desiderio di trasferirsi in luoghi con quadri legislativi più progressisti in cui vivere la propria vita [19].

Le conseguenze del bullismo e delle molestie sono molto gravi. A causa dell'esperienza di bullismo, gli studenti hanno riferito di sentirsi meno sicuri di sé, di essere depressi e di avere meno amici degli altri. Una ricerca condotta dall'Organizzazione Internazionale dei Giovani e degli Studenti LGBTQ mostra il legame tra esperienze negative e tassi di suicidio più elevati tra gli adolescenti LGBT [20].

Purtroppo, la scuola non è solo impreparata ad affrontare questa popolazione, ma anche la famiglia. Questi giovani sono più inclini a incomprensioni e conflitti in famiglia e nei rapporti con gli amici, e sono anche ulteriormente influenzati dai media [21].

Questi fattori, insieme alla mancanza di modelli di ruolo e di un sostegno adeguato, nonché al potenziale conflitto con la famiglia e/o gli amici, possono influenzare il rendimento scolastico (sotto forma di acquisizione di competenze e/o di risultati) e quindi diminuire le opportunità di ingresso nel mercato del lavoro [22].

La ricerca sulle famiglie arcobaleno è limitata e, secondo le leggi nazionali di molti Paesi dell'UE, le famiglie arcobaleno non hanno uno status giuridico uguale a quello delle famiglie tradizionali.

I suddetti problemi di discriminazione basati sul genere e sull'identità sessuale richiamano l'attenzione sull'urgente necessità di combatterli nelle scuole europee.

Sebbene le politiche europee abbiano adottato una serie di misure per combattere i pregiudizi di genere e la discriminazione sessuale, sembra che le scuole, le famiglie e la società nel suo complesso non abbiano ancora strumenti sufficienti per gestire correttamente la diversità. Sono necessarie ulteriori misure concrete per combattere la discriminazione di genere e di sesso nell'istruzione. È necessario trovare soluzioni che coprano tutte le forme di istruzione - formale, non formale e informale - e che mirino a formare tutti gli operatori dell'istruzione e tutte le istituzioni di socializzazione e di educazione con gli strumenti per mettere in pratica i principi della parità di genere e delle pari opportunità.

2.5 Diversità Fisica e Neuropsicologica

La diversità in classe non è solo legata alla classe, alla razza o alla religione, ma anche all'unicità dell'essere umano in termini di sviluppo neuropsicologico e fisico. Così, in ogni classe incontriamo studenti con diversi stili di apprendimento, diverse intelligenze, diversi temperamenti, diverse peculiarità emotive, diverse capacità di concentrazione, ecc.:

1. Alunni con bisogni educativi speciali. Questa categoria comprende gli alunni con difficoltà di apprendimento (dislessia, disgrafia, discalculia), con deficit di attenzione e iperattività, con disturbi dello spettro autistico (DSA) che, come sapete, devono affrontare sfide nell'interazione sociale e nella flessibilità di pensiero, nonché gli studenti dotati che hanno bisogno di ulteriori sfide per sviluppare il loro potenziale.
2. Un'altra categoria è rappresentata da studenti con difficoltà a gestire le emozioni, alcuni dei quali affrontano problemi legati all'ansia e alla depressione.
3. Un'altra categoria comprende gli alunni con disabilità fisiche. Alcuni di loro hanno una mobilità ridotta che richiede l'uso di sedie a rotelle, stampelle o altri dispositivi di assistenza; altri hanno varie disabilità motorie, come, ad esempio, difficoltà nel coordinare i movimenti fini o grossolani. Questi bambini hanno esigenze particolari, dall'accesso a rampe e mobili adattati a dispositivi di assistenza come tastiere speciali.
4. Altri bambini hanno condizioni mediche croniche, per esempio diabete, epilessia, malattie cardiache, che richiedono un monitoraggio medico e talvolta adattamenti del programma scolastico.
5. Non dimentichiamo gli ipovedenti e gli ipoudenti. Gli alunni ipovedenti hanno bisogno di attrezzature speciali, in alcuni casi di testi ingranditi, di materiali in Braille o di tecnologie assistive, mentre gli alunni ipoacusici hanno bisogno di comunicare utilizzando il linguaggio dei segni, l'amplificazione sonora o i sottotitoli.

Tutte queste caratteristiche di diversità neuropsicologica, medica e fisica in una classe non sono un ostacolo, ma un'opportunità per rendere l'istruzione un processo realmente inclusivo. Attraverso l'adattamento, l'empatia e la cooperazione, tutti gli alunni possono imparare a realizzare il proprio potenziale e contribuire allo sviluppo di una società equilibrata e prospera.

Conclusioni

Da quanto detto sopra, il gruppo scolastico ci appare come uno spazio ricco di diversità in cui l'incontro e il dialogo tra le differenze sono inevitabili e in molti casi problematici e complessi. Vivere con gli altri, imparare a vivere con loro, diventa tanto necessario quanto naturale. Sapere che gli individui appartengono a diversi orizzonti culturali e sociali, che ognuno ha modi diversi di percepire la realtà, di relazionarsi con lo spazio, il tempo e il movimento, e con gli altri, diventano elementi sempre più importanti nelle nostre relazioni con

il mondo (Cucoş, 2014). Ogni alunno è portatore di modi unici di pensare, sentire e agire acquisiti attraverso le esperienze precedenti. L'esperto olandese G. Hofstede ha definito questi modi di pensare, sentire e agire programmi mentali o soft ware della mente (Cucoş, 2014). Poiché quasi tutti i discendenti appartengono contemporaneamente a diversi gruppi e categorie di persone, è inevitabile che portino con sé diversi strati di programmazione mentale corrispondenti a diversi livelli di cultura (ad esempio, un livello nazionale, un livello regionale e/o etnico, un livello di classe sociale, ecc.) Va notato che i programmi mentali corrispondenti a questi livelli culturali possono essere parzialmente e/o temporaneamente in conflitto tra loro; non è quindi detto che siano (permanentemente e/o totalmente) in armonia.

La diversità che si incontra nell'ambiente scolastico non è facile da gestire, poiché gli ostacoli legati alle abitudini, ai pregiudizi, alle estrapolazioni, alle incertezze e alle sicurezze personali possono comparire in qualsiasi momento nel modo di affrontarla e sincronizzarla. È chiaro, tuttavia, che le differenze nel modo in cui alunni e insegnanti pensano, sentono e agiscono in un mondo in cui esistono, tuttavia, molti importanti e numerosi problemi comuni sono ancora molto trascurati.

Questo mondo vario e diversificato della scuola e della classe, multiculturale, aperto e dinamico, richiede contemporaneamente il riconoscimento e l'accettazione del relativismo culturale, delle differenze tra individui e gruppi, e una chiara consapevolezza dei limiti della nostra programmazione mentale in relazione ai nostri simili.

La diversità di qualsiasi tipo è quindi un'opportunità preziosa per coltivare l'empatia, il dialogo e il rispetto tra gli alunni. Gli insegnanti possono svolgere un ruolo chiave nel rendere questa diversità un punto di forza del processo educativo, promuovendo un ambiente inclusivo e armonioso.

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EXISTENTIAL VOID AMONG STUDENTS IN ROMANIA: TRIGGERING AND MAINTAINING FACTORS OF THIS STATE

**Prof. univ. Mihaela STOICA PhD.¹, Nicoleta Teodora MAIER (BUNGARDEAN-
MAIER)²**

¹"Dimitrie Cantemir" University of Târgu Mureș, Romania

²Mureș Emergency Clinical Hospital, Romania

Correspondent - Mihaela Stoica: mstoica96@yahoo.com

Abstract

This study aims to identify the existential void among students in Romania. We will dive step by step into the world of the meaning of life: where we can find it, on what "streets" it haunts, and how we can bring it on ours too. We will also walk through the world of logotherapy, including its foundations and more. The meta clinical implications of psychotherapy - what's the deal with it from this point of view? Values, unique meaning, moral conscience: 3 of the main actors on the stage of meaning will be broken down, and we'll see what they do, each one separately. And at the end of the story, we will conclude with the last meaning. The crowning of life by reaching the ultimate meaning, namely, death. The meta-analytic studies that I have included at the end of the theory pages include recent works from different countries around the world. The student population on which they were done, the journals in which they were published, the methodology, and the results. According to these 12 studies, my hypotheses are not only well cemented in a scientifically validated background, but they also find their purpose being a topic that shrugs wherever you stop the globe and press your finger on the map. Which is why I have moved on with them to the practical part. The practical part, the statistics, and the study itself are based on a series of objectives and hypotheses outlined based on the results of the meta-analysis studies. The sample consists of 54 subjects, students aged between 18 and 25. As a methodology, I opted for the PIL questionnaire and a structured interview that I conducted in close connection with the results of the meta-analysis I did before.

Keywords: Existential void, Frankl, the meaning of life

Introduction

The existential void represents one of the most discussed issues in logotherapy and contemporary existential psychology. In the context of modern society, marked by rapid changes, academic pressures, diverse professional options, and a decline in traditional reference points, more young people experience a sense of inner emptiness, loss of direction, and lack of meaning. Recent studies show that the phenomenon is widespread among students, affecting motivation, academic performance, mental health, and overall functioning. This paper synthesizes the foundations of Viktor Frankl's logotherapy, the concept of the existential void and its implications, the role of values, of moral conscience, and of the "ultimate meaning," as

well as a structured meta-analysis of recent scientific literature (2016–2022). The aim is to offer a solid theoretical synthesis that can serve as a conceptual basis for further research.

Logotherapy, developed by Viktor E. Frankl, is based on the premise that the will to meaning is the primary motivation of the human being. While other psychological approaches emphasize the will to pleasure (Freud) or the will to power (Adler), Frankl believes that the human being is fundamentally oriented toward discovering a unique, situationally specific meaning [4, p. 48].

Frankl introduces the concept of noödynamics, defined as the healthy tension between what a person is now and what they must or can become. This tension is not a pathological conflict but a necessary condition for development. Modern biological and psychological models contradict the idea of homeostasis as an ideal state, supporting - like Allport

Bühler or Maslow, in arguing that people tend to maintain the tension oriented toward goals, values, and creation [3, p. 112].

In the logotherapeutic view, meaning can be discovered through three fundamental paths:

Creative values – what a person offers to the world through their work and contributions.

Experiential values – what a person receives from the world through experiences, relationships, beauty, and art.

Attitudinal values – the inner stance adopted in the face of unavoidable situations, including suffering [5, p. 83].

These dimensions reflect the human being's spiritual freedom—the ability to choose one's attitude under any circumstances.

Frankl considers self-transcendence the essence of the human condition. An individual can fulfil themselves only by going beyond their own interests and orienting themselves toward values, causes, relationships, or ideals greater than the self. The clinical and autobiographical examples presented by Frankl, especially those from his experience in the concentration camps, demonstrate that meaning can be found even under extreme conditions. Self-transcendence manifests through the capacity to dedicate oneself to other people, to a mission, or to a task that must be completed. At the same time, it represents a critique of the hedonistic or purely self-referential view of life [4, p. 31].

The existential vacuum refers to the experience of inner emptiness, apathy, lack of direction, or absence of meaning. Frankl considers it a form of *noogenic neurosis*, different from psychodynamic neuroses, because it originates in existential not instinctual frustrations.

The main causes leading to the emergence of the existential vacuum are the loss of traditional reference points (family, cultural, religious), overstimulation and the pressure of multiple choices, society's orientation toward consumption and superficial success, and the collapse of value hierarchies. The existential vacuum can lead to depression, anxiety, aggression, addictive behaviors, academic burnout, or even suicide [5, p. 97].

The meaning of life is unique for each individual and for each situation. There is no universally valid "general meaning"; there are only concrete meanings that must be discovered in the specific moments of existence. Conscience acts as an organ of meaning, guiding the person toward valuable choices. Frankl argues that meaning is not an intellectual construct or a psychological illusion. It is an objective element of existential reality: the human being does not invent it but discovers it [5, p. 75–76].

Conscience as the "guide of meaning" represents the capacity to perceive the unique meaning of each situation. It does not function as a storehouse of universal rules but as a flexible, adaptable guide that optimizes ethical direction in a concrete situation. Therefore,

moral decisions may vary depending on the context, without relativizing the fundamental value of human life.

Frankl describes boundary situations in which individual meaning may require surpassing a generally accepted moral rule. The example of the woman in Auschwitz, who might resort to behaviours contrary to norms to survive, illustrates that sometimes situational meaning can outweigh a universal value. The decisive criterion is the protection of life.

Conscience can be mistaken. Like any human faculty, it is perfectible and influenced by context, emotional maturity, and responsibility. Existential education thus becomes essential for forming discernment and developing critical thinking [3].

Frankl emphasizes that although death is inevitable, it gives unity and finality to life. Ultimate meaning does not annul everyday meanings but crowns them, making individuals more responsible in their choices. Accepting finitude can lead to a more authentic existence, oriented toward what is truly valuable [3].

The meta-analysis of significant studies from the specialized literature between 2017–2022 includes various international studies on the relationship between meaning in life, existential vacuum, and the psychological state of students. The study by Sharma & Kumra [11] presents significant results showing the prevalence of the existential vacuum among students: between 45% and 73% report symptoms associated with it. International students, those from disadvantaged backgrounds, only children, or students in their first years show higher levels. Bronk & Baumsteiger [1] show a strongly negative correlation between presence of meaning in life and depressive symptoms ($r \approx -0.72$), suggesting that the absence of purpose is closely linked to depressive symptomatology in students. Martinez & Rodriguez [9] validate a scale of existential vacuum in youth and show that $\approx 68\%$ of participants report moderate to severe episodes, significantly correlated with depression and social anxiety. Kim & Park [7] find that purpose in life is associated with higher psychological resilience and lower levels of existential vacuum ($r \approx -0.61$), and note that academic pressure remains an important predictor, reported by 57% of participants. The study “Existential Vacuum as a Predictor of Graduate Student...” [14] shows that the existential vacuum consistently predicts academic difficulties at the postgraduate level, suggesting an increased risk of lower performance and dropout. Weber & Schmidt [12] (“Personal Growth Initiative and Existential Fulfillment”) show a strong negative relationship between personal growth initiative and existential vacuum ($r \approx -0.68$) and that increased initiative predicts a reduction in the vacuum after 6 months ($\beta \approx -0.41$). Liu & Zhang [8] show a strong negative correlation between purpose in life and existential vacuum ($r \approx -0.73$) and highlight the mediating role of social support in the effect of purpose on student well-being. Cohen & Cairns [2] show a moderate negative correlation between existential anxiety and purpose in life ($r \approx -0.54$), with stronger effects among first-year students and important predictors such as career uncertainty ($\beta \approx 0.48$). Müller & Fischer [10] show that the existential vacuum completely mediated the stress–depression relationship (indirect effect $\beta \approx 0.41$) and report that community engagement and spiritual practices significantly reduce the vacuum. Yamamoto & Tanaka [13] show that mindfulness strongly moderates the relationship between existential vacuum and burnout (moderation effect $\beta \approx -0.47$) and that a mindfulness program considerably reduces the vacuum ($\sim 37\%$ reduction). Garcia & Martinez [6] show an important negative link between existential vacuum and academic performance ($r \approx -0.58$), accompanied by increased absences ($r \approx 0.45$) and direct effects on GPA ($\beta \approx -0.41$). The study “Life Meaning and Well-being in Indian College Students” [15] shows the protective role of traditional and spiritual practices (reducing the vacuum by about 24%) and highlights the vulnerability of students from rural and disadvantaged environments.

The conclusion of the meta-analysis is that the existential vacuum is a significant predictor of poor mental health and low academic performance. The presence of purpose in life has a protective role, being associated with greater resilience, motivation, and overall functioning. Psychotherapeutic interventions focused on meaning, logotherapy, mindfulness, existential counselling, prove effective in reducing symptoms associated with the existential vacuum. The theoretical synthesis and meta-analytic findings confirm the major relevance of life meaning in youth development. In a socio-cultural context marked by instability and an overabundance of options, the existential vacuum becomes a widespread phenomenon. Understanding the fundamental concepts of logotherapy, the importance of self-transcendence, and the role of moral conscience and values represents a solid foundation for effective psychological interventions.

Research Methodology

The General Objective of the Research

- identification of the existential vacuum among students in Romania, as well as the triggering factors and those that maintain it.

The Secondary Objectives

1. Determining the differences in the level of existential vacuum based on the triggering and maintaining factors.
2. Identifying the triggering and maintaining factors most frequently associated with elevated levels of existential vacuum.
3. Analysis of gender differences, faculty profile (humanities or sciences), year of study (whether final year or not), consumption of media (series, films, social media, electronic games, etc.), family support, engagement in religious/spiritual activities, involvement in volunteer activities, and family pressure.

The Research Hypotheses

1. Students who spend more time on social media, watching series/films, or playing electronic games will have a higher level of existential vacuum (including the component related to suicidal temptation) compared to those who spend little or no time on these activities.
2. Students from humanities faculties experience a higher level of existential vacuum (through the component of fear of death) compared to those from science/technical faculties.
3. Students who do not engage in religious or spiritual activities will have a higher level of existential vacuum (through the component related to suicidal temptation) compared to those who do.
4. There is a negative correlation between existential vacuum and family support (through the component of meaning in life).
5. There is a negative correlation between the level of existential vacuum (through the component of meaning in life) and involvement in volunteer activities.
6. Students who experience high levels of family pressure will have a higher level of existential vacuum (through the component of life satisfaction) compared to those who do not.

7. Final-year students will not have a higher level of existential vacuum (through the component of life satisfaction) compared to students in other years.

Participants

The research sample consists of 54 subjects, 46 of whom are female and 8 male, aged between 18 and 25 years, distributed as follows: 1 subject aged 18, 12 subjects aged 19, 15 subjects aged 20, 12 subjects aged 21, 5 subjects aged 22, 6 subjects aged 23, 1 subject aged 24, and 2 subjects aged 25. Of the total 54 subjects, 24 are enrolled in a humanities faculty and 30 in a science/technical faculty, with 15 of them in their final year.

Material and Method

To assess the existential vacuum, the PIL Test (Crumbaugh & Maholick, 1964) was used, consisting of 20 items. It is the only widely used test for measuring the lack of meaning. The test measures the extent to which a person perceives their life as having purpose, direction, and value. The items capture both the current level of experienced meaning and the individual's overall coherence and orientation toward their existential goals.

To evaluate the triggering and maintaining factors, a structured interview was conducted with questions based on studies included in the meta-analysis. A total of 23 questions were created, covering topics such as exposure to social media, family pressure, family support, involvement in volunteer activities, and engagement in religious or spiritual activities.

Results

Hypothesis 1, which stated that longer time spent on social media, in front of screens, or playing electronic games is associated with a higher level of existential vacuum (through the component of suicidal temptation), is confirmed. A significant relationship was found between time spent on social media and suicidal temptation ($r = .277$, $p < .05$), which may indicate a negative impact of prolonged exposure on mental well-being (Table 1).

Table 1. Significant results for the correlation between time spent on social media and suicidal ideation

Variable	Sense of Life	Life Satisfaction	Freedom	Fear of Death	Suicidal Ideation	Perceived Value of Life
21. How much time do you spend on social media?						
Pearson Correlation	-0.161	-0.122	-0.046	-0.135	0.277*	-0.071
Significance (2-tailed)	0.246	0.378	0.739	0.332	0.043	0.608
N	54	54	54	54	54	54

Hypothesis 2, which states that students from humanities faculties experience a higher level of existential vacuum (through the component of fear of death) compared to students from science/technical faculties, is confirmed. The results show that the statistically significant difference is in the variable “fear of death,” with humanities students exhibiting a significantly higher fear of death (Table 2).

Table 2. Significant results for the comparison between students from humanities and science/technical faculties

Test	Sense of Life	Life Satisfaction	Freedom	Fear of Death	Suicidal Ideation	Perceived Value of Life
Mann–Whitney U	314.500	306.500	335.500	221.000	315.000	296.000
Wilcoxon W	614.500	606.500	635.500	686.000	615.000	596.000
Z	-0.795	-0.936	-0.433	-2.499	-0.876	-1.166
Asymp. Sig. (2-tailed)	0.427	0.349	0.665	0.012	0.381	0.244

Grouping variable: Field of study (Humanities vs. Science/Technical faculties).

Statistical significance is indicated at the 0.05 level (2-tailed).

The significant difference appears for the variable **Fear of Death** ($p = 0.012$).

Hypothesis 3, which stated that students who do not engage in religious or spiritual activities will have a higher level of existential vacuum (through the component of suicidal temptation) compared to those who do, is confirmed. The Kruskal-Wallis test indicated a significant difference for the variable suicidal temptation ($p = 0.029$), which may suggest a potential protective role of religious/spiritual involvement on mental health (Table 3).

Table 3. Significant results for the comparison between engagement in religious/spiritual activities and non-engagement

Test	Sense of Life	Life Satisfaction	Freedom	Fear of Death	Suicidal Ideation	Perceived Value of Life
Kruskal–Wallis H	1.298	0.556	4.527	2.272	9.021	1.297
Df	3	3	3	3	3	3
Asymp. Sig. (2-tailed)	0.730	0.906	0.210	0.518	0.029	0.730

Grouping variable: Engagement in religious/spiritual activities (Yes/No). Statistical significance is indicated at the 0.05 level (2-tailed). A significant difference is observed for the variable **Suicidal Ideation** ($p = 0.029$).

Hypothesis 4, which states that there is a negative correlation between existential vacuum and family support (through the component of meaning in life), is confirmed. The results indicate a significant correlation between family support and the “meaning in life” dimension ($p = 0.036$), suggesting that individuals who receive family support perceive a clearer sense of purpose in life and consequently have a lower level of existential vacuum (Table 4).

Table 4. Significant results for the negative correlation between existential vacuum and family support

Variable	Sense of Life	Life Satisfaction	Freedom	Fear of Death	Suicidal Ideation	Perceived Value of Life
4. Do you feel supported by your family in what you do?						
Pearson Correlation	-0.286*	-0.187	-0.089	-0.047	-0.219	-0.154
Significance (2-tailed)	0.036	0.175	0.522	0.734	0.111	0.267
N	54	54	54	54	54	54

* Correlation is significant at the 0.05 level (2-tailed). Negative values indicate an inverse relationship between perceived family support and the respective existential or psychological dimension.

Hypothesis 5, which states that there is a negative correlation between the level of existential vacuum (through the component of meaning in life) and involvement in volunteer activities, is confirmed. A significant negative correlation was found between involvement in volunteer

activities and the “meaning in life” dimension ($p = -.272$, $p = .047$). This suggests that students who engage in volunteer activities tend to perceive a clearer sense of life and therefore have a lower level of existential vacuum (Table 5).

Table 5. Significant results for the negative correlation between the level of existential vacuum and involvement in volunteer activities

Variable	Sense of Life	Life Satisfaction	Freedom	Fear of Death	Suicidal Ideation	Perceived Value of Life
7. To what extent are you involved in volunteer activities?						
Spearman's rho (Correlation Coefficient)	-0.272*	-0.227	-0.100	-0.080	-0.045	-0.247
Significance (2-tailed)	0.047	0.099	0.472	0.567	0.748	0.072
N	54	54	54	54	54	54

* Correlation is significant at the 0.05 level (2-tailed). Negative coefficients indicate an inverse relationship between involvement in volunteer activities and the respective existential or psychological dimensions.

Hypothesis 6, which states that students who experience high levels of family pressure will have a higher level of existential vacuum (through the component of life satisfaction) compared to those who do not, is confirmed. According to the Kruskal-Wallis test, which evaluates significant differences between multiple independent groups, the significant variable is life satisfaction, indicating that the level of family pressure significantly influences students' life satisfaction (Table 6).

Table 6. Significant results for the association between high levels of family pressure and high levels of existential vacuum

Test	Sense of Life	Life Satisfaction	Freedom	Fear of Death	Suicidal Ideation	Perceived Value of Life
Kruskal-Wallis H	6.600	12.961	1.359	1.349	4.750	5.284
df	4	4	4	4	4	4
Asymp. Sig. (2-tailed)	0.159	0.011	0.851	0.853	0.314	0.259

Grouping variable: *Perceived family pressure regarding personal success*. Statistical significance is indicated at the 0.05 level (2-tailed). A significant difference is observed for the variable *Life Satisfaction* ($p = 0.011$), indicating that perceived family pressure is associated with variations in students' reported life satisfaction.

Hypothesis 7: Final-year students will not have a higher level of existential vacuum (through the component of life satisfaction) compared to students in other years, is confirmed. The significant correlation is between being in the final year and life satisfaction ($p = 0.029 < 0.05$), indicating that final-year students tend to have higher life satisfaction compared to students in lower years (Table 7).

Table 7. Significant results for the correlation between final-year status and the level of existential vacuum

Variable	Sense of Life	Life Satisfaction	Freedom	Fear of Death	Suicidal Ideation	Perceived Value of Life
Are you in your final year of study?						
Spearman's rho (Correlation Coefficient)	-0.041	0.297*	0.086	0.044	0.062	-0.100
Significance (2-tailed)	0.767	0.029	0.535	0.753	0.655	0.472
N	54	54	54	54	54	54

* Correlation is significant at the 0.05 level (2-tailed). A significant positive association is observed for *Life Satisfaction* ($p = 0.029$), indicating that final-year status is related to variations in students' reported life satisfaction

Conclusion

The research results show that:

1. Students who spend more time on social media have a higher level of existential vacuum, as indicated by the significant relationship identified between time spent on social media and suicidal tendencies.
2. Students from humanities faculties experience a higher level of existential vacuum, as shown by the significant relationship between fear of death and the humanities profile.
3. Students who do not engage in religious or spiritual activities have a higher level of existential vacuum, as indicated by the relationship between not participating in these activities and suicidal tendencies.
4. Students who receive family support perceive a clearer sense of purpose in life and consequently have a lower level of existential vacuum.
5. Students who engage in volunteer activities tend to perceive a clearer sense of life and therefore experience a lower level of existential vacuum.
6. The level of family pressure influences students' life satisfaction.
2. Final-year students tend to have higher life satisfaction compared to students in lower years.

All hypotheses are confirmed, showing that social media, family support, volunteer activities, engagement in religious/spiritual activities, the level of family pressure, faculty profile, and being in the final year are all factors that in one way or another influence the level of existential vacuum.

The results obtained help us identify possible triggering and maintaining factors of existential vacuum, which is very important because we can intervene on them to improve quality of life and know what to do or avoid doing to combat existential vacuum.

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THE PREDICTIVE VALUE OF EMOTIONAL INTELLIGENCE IN RELATION WITH THE ACCEPTANCE OF ARTIFICIAL INTELLIGENCE

Lecturer PhD Traian MOLDOVAN

*University of Arts of Târgu Mureș, Career Counseling and Guidance Center
Corresponding author: Traian Moldovan: traianmol@yahoo.com*

Abstract

Artificial intelligence (AI) is increasingly integrated into multiple domains of everyday life, raising important questions regarding user acceptance and human-AI interaction. While existing acceptance models emphasize cognitive and behavioral determinants of AI adoption, less attention has been given to the role of emotional factors. This study investigates the relationship between emotional intelligence (EI) and the acceptance of AI. To this end, a dedicated assessment instrument was developed to measure AI acceptance across key dimensions, including AI identity, rights and responsibilities, decision-making autonomy, and social acceptance in real-world contexts. By examining emotional intelligence as a predictor of attitudes toward AI, the study contributes to a deeper understanding of individual differences in AI acceptance and offers insights that may support the responsible and socially sustainable integration of advanced AI systems.

Keywords: Artificial Intelligence, Emotional Intelligence, AI Acceptance, Human-AI Interaction, Emerging Technologies

1. Introduction

Artificial Intelligence (AI) is the representative technology of this historical period due to its ability to optimize human competencies at low cost [1]. It is estimated that artificial intelligence will become a significant component of most fields of activity, with its projected financial contribution to the global economy expected to reach approximately USD 15.7 trillion [2]. This type of technology could improve people's daily lives through significant advances in healthcare [3], customer service [2], education [4], and transportation [5].

To facilitate the large-scale adoption of artificial intelligence, it is necessary to increase both the volume and diversity of research aimed at understanding the factors that contribute to its acceptance among users. In general, user acceptance of a particular product or service can be defined as the behavioural intention or willingness to use, purchase, or try that product or service. Since AI can bring benefits to society through progress in certain domains, it is essential to understand the factors that facilitate the acceptance and adoption of this technology [6, 7, 8, 9].

Within a meta-analytical study [1], the author reviews the theoretical models that attempt to explain the acceptance of artificial intelligence. The author states that the most appropriate existing models at present are:

a. The TAM model (Technology Acceptance Model) – the most flexible of the existing models, whose usefulness has been demonstrated through numerous studies in the specialized literature that employ it.

b. The AIDUA model (Acceptance, Intention, and Use of AI) – the most recently developed theoretical model which, although not as widely used as the TAM model, has nevertheless shown promising results (e.g., significant predictive power). AIDUA has been used primarily to study user acceptance of AI devices in customer service roles that could replace humans (e.g., hospitality services). In this context, we initiated a study examining the relationship between emotional intelligence (EI) and the acceptance of artificial intelligence (AI). To achieve this objective, an instrument was developed to assess the level of acceptance of artificial intelligence. The factors examined include the recognition of AI identity, its rights and responsibilities, decision-making autonomy, and social acceptance in real-world applications. A better understanding of the emotional implications related to AI is essential in preparing individuals to accept these technologies and may contribute to increased social comfort in the face of cutting-edge technological innovations. The research was conducted in stages: emotional intelligence was assessed beginning in 2023, and a questionnaire to evaluate the level of acceptance of artificial intelligence was developed in February 2025.

2. Objectives

1. Assessment of the relationship between the level of knowledge about artificial intelligence and its perception as an “Autonomous Identity Structure.” The autonomous identity structure of artificial intelligence is described through identity recognition, rights and responsibilities, and decision-making autonomy.
2. Identification of differences in the acceptance of artificial intelligence from the perspective of demographic variables (gender, age, and occupation).
3. Evaluation of the predictive value of emotional intelligence in relation to the acceptance of artificial intelligence.

3. Hypotheses

1. There is a positive and significant correlation between the level of knowledge/information regarding artificial intelligence and its acceptance as an autonomous identity structure.
2. There are significant differences in the acceptance of artificial intelligence depending on the gender, age, and occupation of the research participants.
3. The non-cognitive abilities, competencies, and skills described by emotional intelligence represent predictive factors in the acceptance of artificial intelligence.

4. Samples Structure

The research participants were grouped into samples representing students, graduates, and teaching staff of the University of Arts of Târgu Mureș, with participation in the study being voluntary. The total number of research participants was 45. They were categorized according to nominal variables, considering gender, age, and occupation.

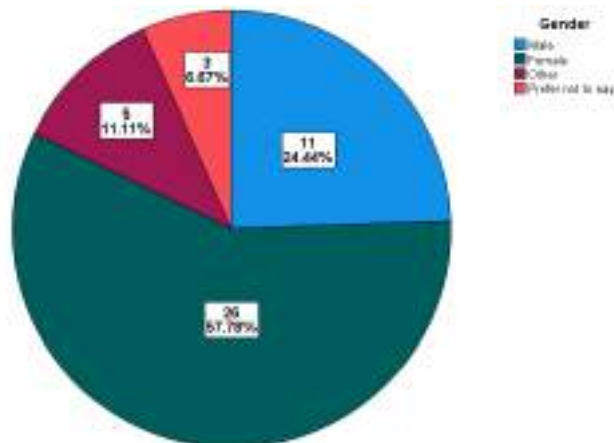


Figure 1. Distribution of research participants by gender

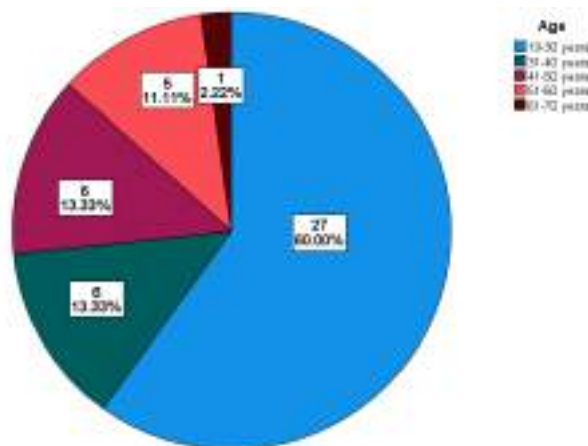


Figure 2. Distribution of research participants by age

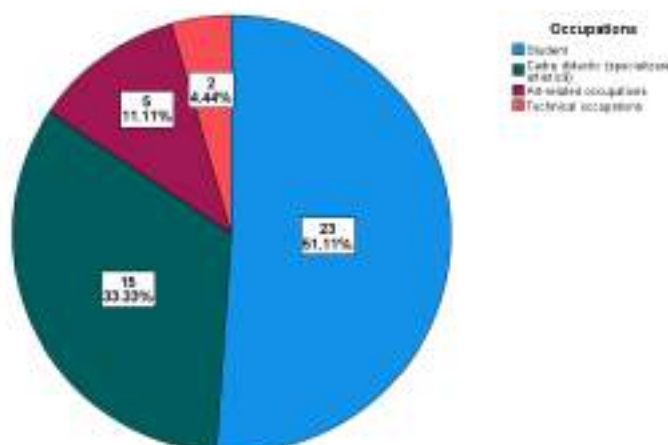


Figure 3. Distribution of research participants by occupation

5. Research Instruments

a. The Bar-On Emotional Intelligence Inventory (Emotional Quotient Inventory).

EQ-i [10] is an empirically developed, multifactorial, and theoretically eclectic test designed to measure emotional intelligence. It is the result of more than 17 years of research on the

concept, involving studies and experiments that extended across more than 10 countries, in an effort to develop a cross-cultural approach to the description and assessment of emotional intelligence. From a structural perspective, the questionnaire reflects Reuven Bar-On's conception of social-emotional intelligence. According to this model, this type of intelligence is based on five meta-factors: intrapersonal, interpersonal, stress management, adaptability, and general mood. EQ-i is an aptitude test, as it primarily evaluates performance potential rather than actual performance (that is, the potential to succeed rather than success itself). It is more process-oriented than outcome-oriented, which is why the measurement of the emotional intelligence quotient is conducted using verbal items similar to those found in personality tests.

The test is organized into five meta-factors (composite scales) and 15 content scales.

The meta-factors and scales are described in detail from the perspective of *high* and *low* scores.

The Intrapersonal meta-factor includes *Self-respect*, *Emotional self-awareness*, *Assertiveness*, *Independence*, and *Self-actualization*.

The Interpersonal meta-factor includes *Empathy*, *Social responsibility*, and *Interpersonal relationships*.

Stress Management includes *Stress tolerance* and *Impulse control*. *Adaptability* includes *Reality testing*, *Flexibility*, and *Problem solving*.

General Mood includes *Optimism* and *Happiness*. In addition, a total EQ score (EQ Total) is provided.

b. The Acceptance of Artificial Intelligence as an Anthropocentric Entity Questionnaire (Appendix 1.)

The Questionnaire on the Acceptance of Artificial Intelligence as an Anthropocentric Entity serves several important purposes. First, it allows for the assessment of research participants' perceptions of artificial intelligence, providing a detailed understanding of how AI can be integrated into everyday life. The results obtained from the application of the questionnaire enable the exploration of relationships between AI acceptance and various demographic factors, such as age, education, or professional field, thus offering an overall picture of the diversity of existing perceptions. In the long term, such an instrument could be used as a basis for developing educational strategies aimed at promoting a deeper understanding and broader acceptance of artificial intelligence among the population. Ultimately, a questionnaire of this type can also serve as a mechanism for monitoring changes in social perceptions of artificial intelligence as the technology evolves and becomes an integral part of daily life. Initially, the structure of the questionnaire included four main factors (Benefits and risks of artificial intelligence, Perception of artificial intelligence as an "Autonomous Identity Structure," Social acceptance, and Emotional impact) and one secondary factor (Knowledge about artificial intelligence). The factor referring to the Perception of artificial intelligence as an "Autonomous Identity Structure" was constructed taking into account three constructs: Identity recognition, Rights and responsibilities, and Decision-making autonomy. The questionnaire contains 16 items, the content of which is consistent with the factors mentioned above. The data collected using the newly developed instrument were processed and analyzed using a set of statistical analyses to evaluate construct validity and to verify reliability (fidelity). To assess construct validity, an Exploratory Factor Analysis (EFA) was conducted, an analysis required for a newly developed instrument for which a clear factorial structure had not previously existed. The main reference points of the exploratory factor analysis are presented below.

5.1 Factor Analysis

Table 1. KMO and Bartlett's test values

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.791
Bartlett's Test of Sphericity	Approx. Chi-Square	296.961
	df	91
	Sig.	.000

The value of the sampling adequacy index, which measures the cumulative variance within the items, Kaiser–Meyer–Olkin (KMO) = 0.791. The authors of the index propose a reference table for its interpretation, with mediocre values ranging between 0.60 and 0.69. The value obtained in the present study falls within the acceptable range, an interval considered adequate for factor analysis [11]. The value of Bartlett's test of sphericity = 296.961 is significant at the $p < 0.01$ level, indicating that the observed correlation matrix differs from a singular matrix, thus confirming the existence of linear relationships among the introduced variables [12] and supporting the presence of multiple common factors [13]. Given the high significance of both indices, the application of the factor reduction procedure is justified.

Table 2. Total variance explained

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.900	35.003	35.003	4.900	35.003	35.003	4.500	32.140	32.140
2	2.104	15.028	50.031	2.104	15.028	50.031	1.886	13.474	45.613
3	1.718	12.274	62.305	1.718	12.274	62.305	1.866	13.328	58.942
4	1.315	9.393	71.698	1.315	9.393	71.698	1.786	12.756	71.698
5	.723	5.164	76.862						
6	.583	4.165	81.027						
7	.519	3.705	84.732						
8	.471	3.361	88.093						
9	.460	3.288	91.381						
10	.421	3.008	94.390						
11	.333	2.381	96.771						
12	.207	1.480	98.251						
13	.155	1.108	99.359						
14	.090	.641	100.000						
Extraction Method: Principal Component Analysis.									

In Table 2, Total Variance Explained, it can be observed that 14 factors were generated, of which only 4 met the criterion for selection, having eigenvalues greater than 1. Under the initial eigenvalue conditions, the variance explained by Factor I is 35.003, by Factor II is 15.028, by Factor III is 12.274, and by Factor IV is 9.393. The total variance explained by the four factors is 71.698. In the second situation, that of the extraction sums of squared loadings, the situation does not change. Thus, in the second phase, the variance loadings for each factor and the cumulative variance of the variables remain the same as in Phase I. After rotation, the loadings are modified in a relevant manner: the variance explained by Factor I decreases to 32.140, the variance explained by Factor II decreases to 13.474, the variance explained by Factor III

increases to 13.328, and the variance explained by Factor IV increases to 12.756. The total variance explained by the four factors remains at the value identified before rotation. It can be observed that rotation leads to a certain homogenization of the saturation values of the four factors, with Factors I and II losing saturation in favor of Factors III and IV. The most commonly used type of rotation (Varimax) was selected for the analysis.

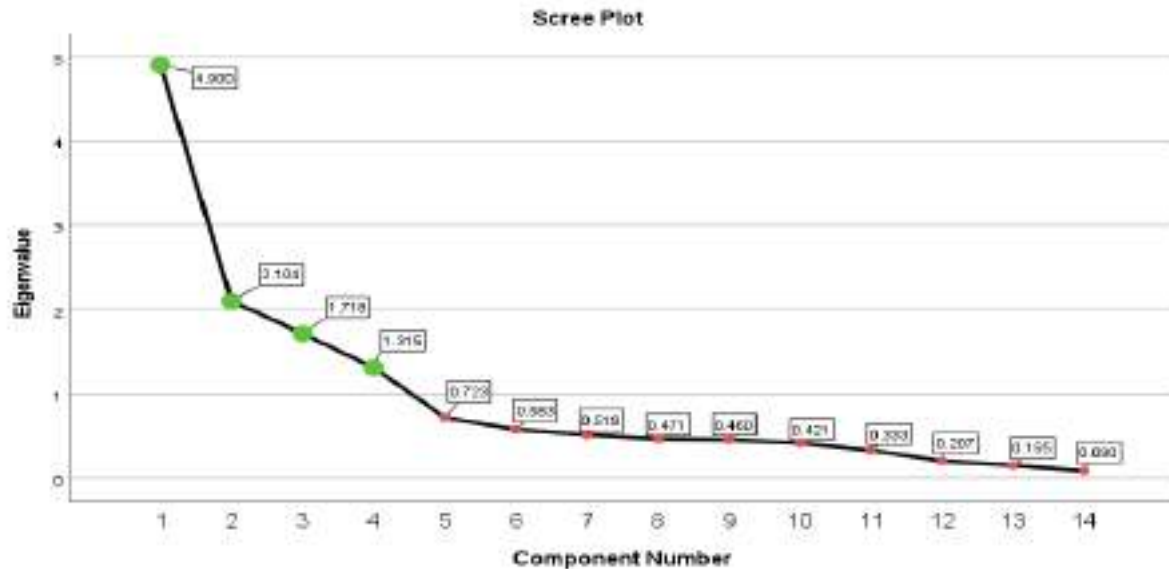


Figure 4. Scree plot of the principal components

Table 3. Rotated factor matrix
Rotated Component Matrix^a

	Component			
	1	2	3	4
How comfortable do you feel with the idea of using artificial intelligence in the workplace?	.886	-.047	.010	.216
What is your level of acceptance regarding the integration of artificial intelligence into the education system?	.832	.206	.112	-.044
What is your level of acceptance regarding the integration of artificial intelligence into the arts?	.809	-.004	.105	-.303
What is your level of acceptance regarding the integration of artificial intelligence into transportation?	.784	.008	.064	.061
How comfortable do you feel with the idea of integrating artificial intelligence into family or couple life?	.749	.015	.251	.155
What is your level of acceptance regarding the integration of artificial intelligence into the healthcare system?	.688	.186	-.199	.432
How comfortable do you feel with the idea of using artificial intelligence as a form of entertainment?	.603	.209	.202	-.051
How concerned are you about the potential risks of using artificial intelligence?	-.124	.861	.032	.064
How important do you think the implementation of regulations and policies for the responsible use of artificial intelligence will be in the future?	.190	.709	-.374	-.204
How comfortable do you feel with the benefits that artificial intelligence can bring?	.380	.689	.057	.220
In your opinion, should artificial intelligence have rights and responsibilities similar to those of human beings?	.072	-.122	.925	-.005
In your opinion, should artificial intelligence be recognized as an entity with its own identity?	.371	.024	.805	.132
In your opinion, should artificial intelligence have the ability to make autonomous decisions without human intervention?	.117	-.083	-.055	.852
In your opinion, do you think artificial intelligence could develop a form of identity or self-awareness in the future, similar to that of humans?	-.040	.147	.213	.769
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.				
a. Rotation converged in 5 iterations.				

In Table 3, the items included in each factor after rotation are presented, ordered according to their factor loadings. Factor I was composed of the following items: Item 14 = 0.886, Item 10 = 0.832, Item 12 = 0.809, Item 13 = 0.784, Item 15 = 0.749, Item 11 = 0.688, and Item 16 = 0.603. The items included in this factor describe the components of social acceptance and emotional impact, which were initially grouped separately. The factor analysis grouped these items within the same factor, a result that we consider logical, although it was not initially anticipated. Given that these items refer to types of interpretations related to socio-emotional competencies—competencies that are structurally and functionally unified—such a rearrangement of items was to be expected. Factor II retained the original items in its structure, the only difference being their rearrangement according to the degree of saturation, as follows: Item 4 = 0.861, Item 5 = 0.709, and Item 3 = 0.689. It is particularly interesting that Factor III (*“Perception of Artificial Intelligence as an Autonomous Identity Structure”*), initially constructed as a unitary factor based on three constructs - *Identity recognition, Rights and responsibilities, and Decision-making autonomy* - was divided into two separate factors following the factor analysis. One factor grouped the items related to rights, responsibilities, and identity recognition (Item 7 = 0.925, Item 6 = 0.805), while the other grouped the items related to decision-making autonomy (Item 8 = 0.852, Item 9 = 0.769).

Thus, the proposed instrument exhibits a factorial structure consisting of four main components and one secondary component. The difference lies in the fact that two factors were merged, and one was separated, with items rearranged according to their respective loadings. At the end of the procedure, the questionnaire was restructured by rearranging the items based on the results of the factor analysis, and new composite scale scores were generated in the database (using the Compute method in SPSS) for the following dimensions: *AI rights, responsibilities, and identity recognition, AI decision-making autonomy, and AI social acceptance and emotional impact*.

5.2 Reliability Analysis

This type of procedure allows for the verification of the internal consistency of the items. It enables the assessment of the fidelity/reliability of the constructed instrument, with the coefficient calculated for this purpose being Cronbach’s alpha, which measures the covariance among item values. From a theoretical perspective, the coefficient can take values between 0 and 1; however, in extreme cases, values greater than 1 or even negative values may occasionally be obtained. There is no absolute standard regarding the magnitude that a Cronbach’s alpha coefficient should reach in order to indicate adequate reliability. Generally, values around 0.90 are considered “excellent,” those around 0.80 “very good,” and those around 0.70 “adequate”. Some authors, however, also accept values as low as 0.60, but only in exploratory studies [13]. The value of Cronbach’s alpha for the Acceptance of Artificial Intelligence as an Anthropocentric Entity Questionnaire can be considered very good.

Tabel 4. Reliability analysis

Reliability Statistics	
Cronbach's Alpha	N of Items
.820	14

6. Statistical Processing and Interpretation.

At the beginning of the statistical analysis, we aim to verify whether the data sets to be used meet the assumption of normality. The distribution of scores should be symmetrical or normal in order for the statistical techniques employed to achieve maximum efficiency. There are several approaches for verifying this assumption. Thus, indices of skewness and kurtosis can be calculated, which highlight shifts of the distribution to the left or right, as well as its amplitude (peaked-leptokurtic; flattened-platykurtic). The values of these two indices are calculated by computing the ratio between each index score and its standard error. If the resulting value falls within the interval of ± 1.96 , the collected data can be considered to meet the assumption of statistical normality, and subsequent analyses may be conducted using parametric statistical indices. On the other hand, in order to make accurate assumptions regarding statistical normality, it is recommended to compute specific statistical tests, namely the Kolmogorov–Smirnov (K–S) and Shapiro–Wilk (S–W) tests. In the case of a smaller sample size, visual inspection of histograms is particularly important for assuming statistical normality [14, 15]. For the data set used in this study ($N < 50$), the appropriate threshold for skewness and kurtosis indices is ± 1.96 , and the Shapiro–Wilk normality test may be considered more powerful and sensitive. Our data set largely meets the assumption of normality across the majority of variable scores; therefore, statistical processing was conducted using parametric statistical indices.

6.1 Correlational Study

In the case of the first study (testing the first formulated hypothesis), correlation scatterplots were constructed and the Pearson correlation coefficient was calculated. A positive and significant correlation was identified between the level of knowledge/information regarding artificial intelligence and its acceptance as an autonomous identity structure.

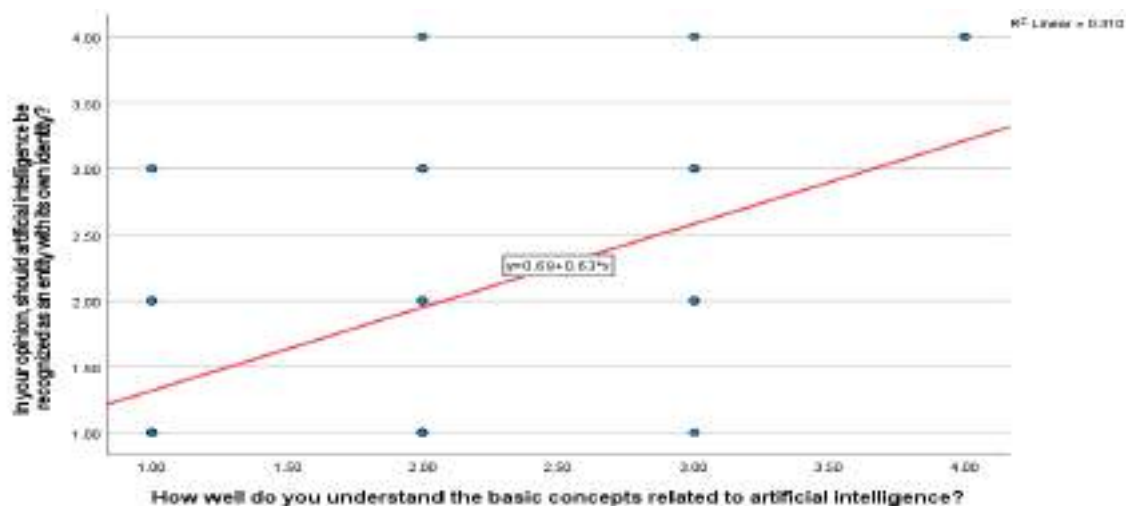


Figure 5. Correlation scatterplot

Tabel 5. Pearson parametric correlations

		Correlations			
		In your opinion, should artificial intelligence be recognized as an entity with its own identity?	In your opinion, should artificial intelligence have rights and responsibilities similar to those of human beings?	In your opinion, should artificial intelligence have the ability to make autonomous decisions without human intervention?	In your opinion, do you think artificial intelligence could develop a form of identity or self-awareness in the future, similar to that of humans?
How well do you understand the basic concepts related to artificial intelligence?	Pearson Correlation	.557**	.337*	.382**	.351*
	Sig. (2-tailed)	.000	.024	.010	.018
	N	45	45	45	45
**. Correlation is significant at the 0.01 level (2-tailed).					
*. Correlation is significant at the 0.05 level (2-tailed).					

The scatter of points in the correlation diagram (figure 5) is arranged linearly and upward, indicating a directly proportional relationship between the variable values, that is, a positive correlation. The higher the level of knowledge/information regarding artificial intelligence, the higher the level of acceptance of artificial intelligence as an autonomous identity structure. The Pearson correlation coefficients (tabel 5) have significant values at significance thresholds of $p < 0.05$ or $p < 0.01$.

6.2 Comparative Study

For the comparative study, Analysis of Variance (One-Way ANOVA) was used, as there were more than three groups to be compared for each demographic variable. The results are presented only for the demographic variable “Occupation.” No significant differences were found regarding the acceptance of artificial intelligence based on the gender and age of the research participants.

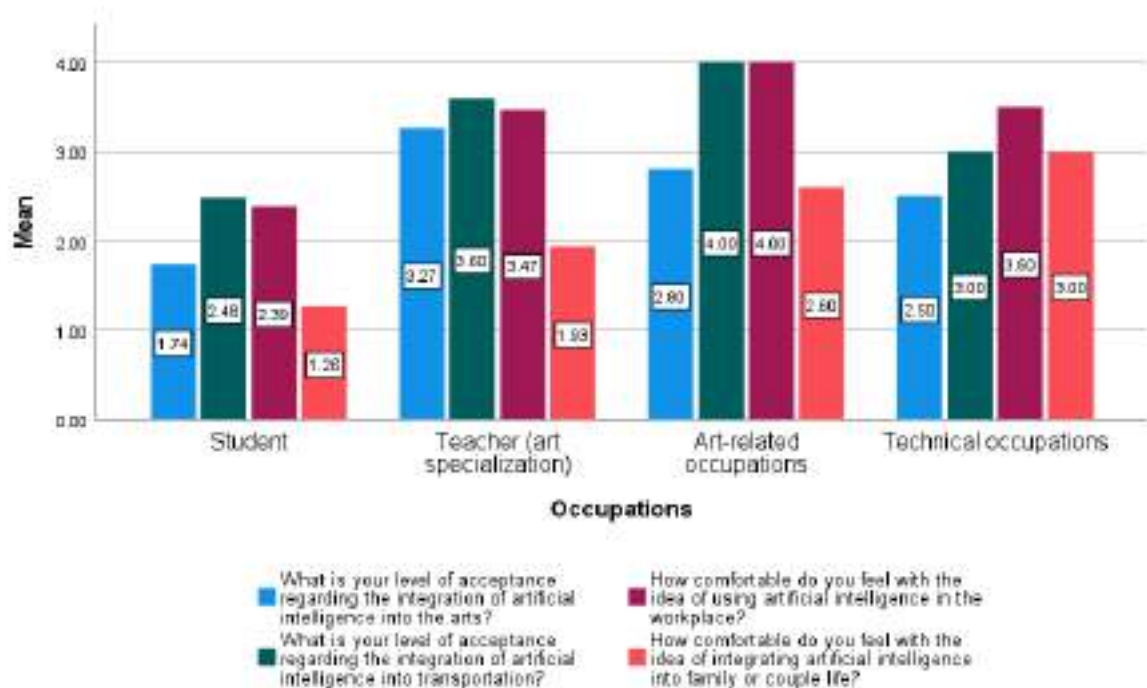


Figure 6. Clustered bar chart

It can be observed that the lowest level of acceptance of artificial intelligence was found among students, while a notable increase in acceptance is evident among teaching staff and individuals with artistic and technical occupations. Due to the small sizes of the latter two samples (11.11% and 4.44% of the total participants), there are reservations regarding the interpretation of the significance of these differences, even though they are present.

Table 6. ANOVA

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
How well do you understand the basic concepts related to artificial intelligence?	Between Groups	22.132	3	7.377	5.970	.002
	Within Groups	50.668	41	1.236		
	Total	72.800	44			
What is your level of acceptance regarding the integration of artificial intelligence into transportation?	Between Groups	16.572	3	5.524	4.412	.009
	Within Groups	51.339	41	1.252		
	Total	67.911	44			
How comfortable do you feel with the idea of using artificial intelligence in the workplace?	Between Groups	17.266	3	5.755	5.162	.004
	Within Groups	45.712	41	1.115		
	Total	62.978	44			
How comfortable do you feel with the idea of integrating artificial intelligence into family or couple life?	Between Groups	12.676	3	4.225	5.012	.005
	Within Groups	34.568	41	.843		
	Total	47.244	44			

The F values (5.970, 4.412, 5.162, 5.012) are significant at a $p < 0.01$ significance level for the acceptance of integrating artificial intelligence into the arts and transportation, as well as for the use of artificial intelligence in the workplace and in family/couple life.

Table 7. Multiple Comparisons – Bonferroni

Multiple Comparisons							
Bonferroni							
Dependent Variable	(I) Occupations	(J) Occupations	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
What is your level of acceptance regarding the integration of artificial intelligence into the arts?	Student	Teacher (art specialization)	-1.52754*	.36894	.001	-2.5504	-.5047
		Art-related occupations	-1.06087	.54854	.360	-2.5816	.4599
		Technical occupations	-.76087	.81953	1.000	-3.0329	1.5112
What is your level of acceptance regarding the integration of artificial intelligence into transportation?	Student	Teacher (art specialization)	-1.12174*	.37138	.026	-2.1513	-.0922
		Art-related occupations	-1.52174	.55216	.052	-3.0525	.0090
		Technical occupations	-.52174	.82494	1.000	-2.8088	1.7653
How comfortable do you feel with the idea of using artificial intelligence in the workplace?	Student	Teacher (art specialization)	-1.07536*	.35043	.023	-2.0469	-.1038
		Art-related occupations	-1.60870*	.52102	.022	-3.0531	-.1643
		Technical occupations	-1.10870	.77842	.972	-3.2667	1.0494
How comfortable do you feel with the idea of integrating artificial intelligence into family or couple life?	Student	Teacher (art specialization)	-.67246	.30474	.198	-1.5173	.1724
		Art-related occupations	-1.33913*	.45308	.031	-2.5952	-.0830
		Technical occupations	-1.73913	.67692	.084	-3.6158	.1375

*. The mean difference is significant at the 0.05 level.

The post-hoc analysis was conducted in order to perform additional comparisons between groups after it had been established that significant differences existed among their means. The Bonferroni method was selected because it provides more effective control of Type I errors (α) and, consequently, a lower risk that statistically significant results are the consequence of random variations in the data.

6.3 Predictive Study

The main reasons for proposing such an approach are based on the fact that predictive studies in psychology are crucial for anticipating individuals' behaviors and psycho-emotional responses in the context of interaction with various sociocultural variables. Based on these evidence-based practices, more effective therapeutic interventions can be developed, or the optimal implementation of social policies can be substantiated. To test the third hypothesis, a multiple regression procedure was employed in order to continue and complement the ideas and conclusions previously presented and formulated. Such an approach allows for the prediction (estimation) of the values of certain variables (the criterion variable—denoted as Y—acceptance of artificial intelligence) based on the values of other variables (the predictor variable—denoted as X—dimensions of emotional intelligence).

The magnitude of the criterion variable is estimated and explained by reference to the values of the predictor variables. From the perspective of the type of regression procedure used in this research, Automatic Linear Modelling was considered optimal, a procedure available starting with version 19 of the SPSS software. The arguments in favor of using this type of procedure are as follows: automatic variable selection, automatic data processing, and superior graphical presentation of results. Predictive models of artificial intelligence acceptance were developed for all variables (items) included in the construction of the AI acceptance questionnaire, as well as for the composite scales resulting from the factor analysis. From the predictor perspective, the global EQ score was initially entered into the predictive model, followed by the scores of the five composite scales, and finally the scores of the 15 content scales. The most relevant predictive models are presented in the following sections.

6.3.1 Predictive Model of AI Rights, Responsibilities, and Identity Recognition

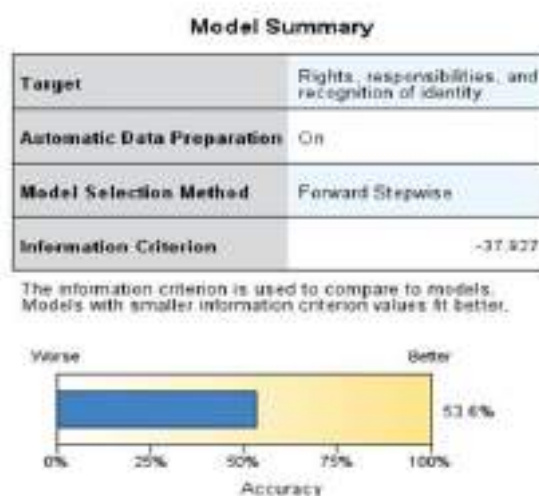


Figure 7. Summary of the predictive model for the criterion “AI rights, responsibilities, and identity recognition”

The analysis of Figure 7 reveals that the predictive model demonstrates reasonable accuracy, with an adjusted R^2 (Adjusted R Square) value of 53.6%. This value can be considered acceptable, as it falls within the 40–60% range [14], indicating that a sufficient proportion of the variance in the dependent (criterion) variable is explained by the variables included in the predictive model.

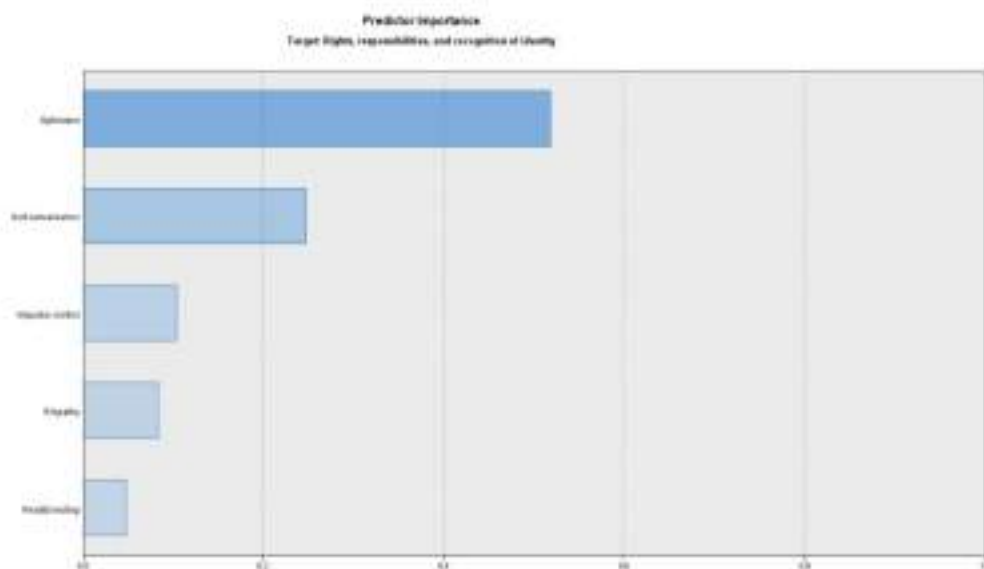


Figure 8. List of predictors included in the model according to their relevance

Regarding the list of the most important predictors identified for explaining the variance of the criterion “AI rights, responsibilities, and identity recognition,” these are presented in Figure 8, in descending order of their importance: Optimism (52%), Self-actualization (25%), Impulse control (10%), Empathy (8%), and Reality testing (5%).

6.3.2. Predictive Model of Social Acceptance and Emotional Impact of Artificial Intelligence

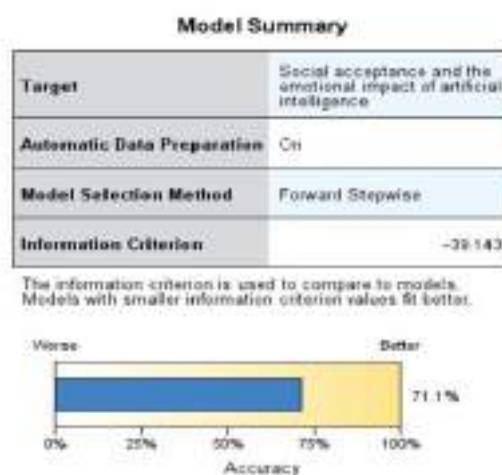


Figure 9. Summary of the predictive model for the criterion “Social acceptance and emotional impact of artificial intelligence.”

The analysis of Figure 9 indicates good accuracy of the predictive model, with an adjusted R^2 (Adjusted R Square) value of 71.1%. In this case, the automatic modelling procedure reveals

a strong model that explains a significant proportion of the variance (60–80%) [14], with the dependent (criterion) variable being well explained by the variables included in the predictive model.

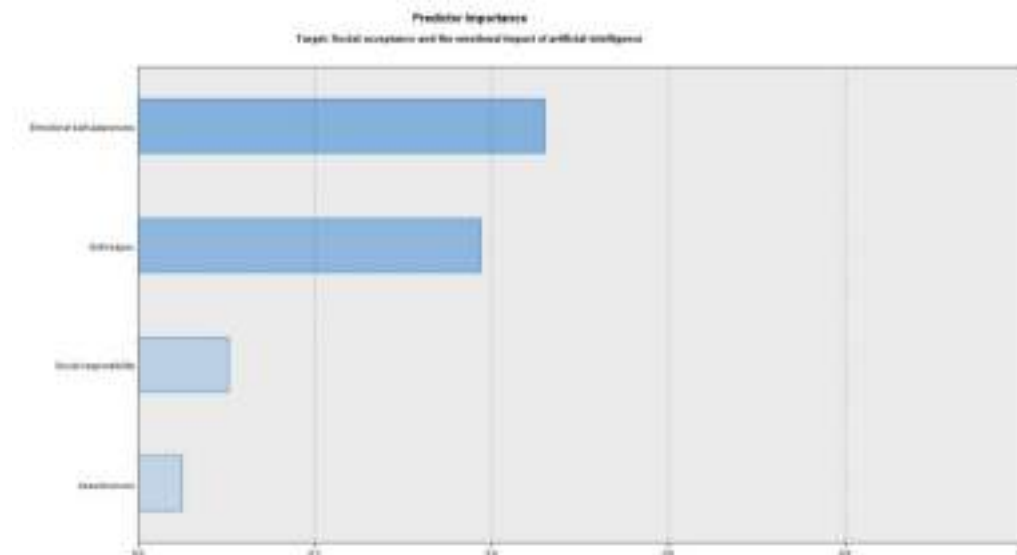


Figure 10. List of predictors included in the model according to their relevance

Within this predictive model, the most important predictors identified for explaining the variance of the criterion “Social acceptance and emotional impact of artificial intelligence” were: Emotional self-awareness (46%), Self-respect (39%), Social responsibility (10%), and Assertiveness (5%). For the criterion “What is your level of acceptance regarding the integration of artificial intelligence into the education system?”, there is also a strong predictive model, with an adjusted R^2 (Adjusted R Square) value of 73.7%. The list of predictors explaining this criterion is hierarchically similar, with minor differences in the percentage of explained variance.

7. Conclusions. Advantages and Limitations of the Research

It is evident that, in order to implement artificial intelligence on a large scale, there is a need to increase both the number and diversity of studies aimed at understanding the factors that contribute to user acceptance. In general, user acceptance of a product or service can be defined as the behavioral intention or willingness to use, purchase, or try that product or service. Since AI can bring benefits to society through progress in certain domains, it is essential to understand the factors that facilitate the acceptance and adoption of this technology [6, 7, 8, 9]. The research conducted at the University of Arts of Târgu Mureș aims to complement the existing body of studies in the specialized literature by proposing a research design and instruments intended to clarify the role of non-cognitive competencies in the acceptance of AI. The instrument developed for this research, although applied to a relatively small number of participants, meets several scientific criteria related to the validity and reliability of psychological tests, representing an important starting point for future studies. The use of this questionnaire alongside a scientifically validated instrument standardized for the Romanian population (EQ-i), as well as the achievement of significant results based on multiple types of models and experimental designs, confers a set of noteworthy psychometric qualities to the instrument.

The hypotheses formulated at the beginning of the research are partially confirmed. The strong correlations identified demonstrate that individuals who possess extensive knowledge about artificial intelligence agree that it should be recognized as an entity with its own identity, should have rights and responsibilities similar to those of human beings, and should be capable of autonomous decision-making without human intervention. These individuals also agree that, in the future, artificial intelligence could develop a form of identity or self-awareness similar to that of humans. From a comparative perspective, significant differences were identified only for the demographic variable “Occupation.” Teaching staff exhibit a higher level of acceptance of artificial intelligence than students with regard to the following variables: acceptance of artificial intelligence in the arts, transportation, the workplace, and family/couple life. Although other significant differences were also observed, reservations are expressed regarding their interpretation due to the small sample sizes associated with technical and artistic occupations. The third stage of the research provided the opportunity to develop predictive profiles regarding the acceptance of artificial intelligence from the perspective of the non-cognitive abilities, competencies, and skills described by emotional intelligence. The two most important predictive profiles of individuals who accept artificial intelligence are:

1. The predictive profile of individuals who accept ***“AI rights, responsibilities, and identity recognition”*** can be described through optimism and positive attitudes, even in the face of adversity. These individuals are hopeful and not easily discouraged. They tend to see the positive side of situations and consistently maintain a positive outlook. They adapt easily to difficult or stressful circumstances. They are individuals who strive to fully develop their abilities, capacities, talents, and themselves as a whole. They enjoy learning new things and are generally passionate about their field of activity. They are capable of controlling aggressive and hostile impulses, as well as irresponsible behavior. Rather than exaggerating emotional reactions, they take sufficient time to understand why they feel a certain way. Aware of others’ emotions, these individuals understand and appreciate why people feel the way they do and show genuine concern for others. They are also able to assess the correspondence between what they experience subjectively and what exists objectively in reality. They are realistic and grounded individuals, constantly seeking objective and pragmatic evidence to confirm, justify, and support their feelings and actions.
2. The predictive profile of individuals oriented toward ***social acceptance and the emotional impact of artificial intelligence*** is characterized by high abilities in recognizing their own feelings and emotions. They can easily differentiate them, understand what they feel and why, and are aware of what has caused those experiences. They understand the impact their emotions have on their opinions and attitudes. Moreover, they find it easy and enjoyable to share their emotions with others. These individuals are self-confident, with a high level of self-esteem and a well-developed sense of identity and personal adequacy. They possess a high level of energy for achieving personal potential. They are socially responsible individuals with strong social awareness, who assume responsibility toward the community and are cooperative and constructive. They maintain high moral and ethical standards and would not intentionally harm another person, nor would they knowingly violate the law. They are capable of openly expressing their emotions and defending their beliefs, thoughts, and opinions, as well as expressing disagreement when they feel it is necessary.

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Appendix 1.

The Acceptance of Artificial Intelligence as an Anthropocene Entity Questionnaire (new factorial structure)

Please evaluate, on a scale from 1 to 5 (1 = minimum, 5 = maximum), your knowledge, perceptions, and feelings regarding artificial intelligence. Your responses are confidential.

Demographic Information: Age: _____ Gender: _____ Occupation: _____

I. Knowledge about Artificial Intelligence:

1. How well do you understand the basic concepts related to artificial intelligence?

1	2	3	4	5

2. How familiar are you with the different types of artificial intelligence (Narrow AI, General AI, Machine Learning AI, Natural Language Processing – NLP, Expert Systems AI, Affective Computing AI)?

1	2	3	4	5

II. Benefits and Risks of Artificial Intelligence

3. How concerned are you about the potential risks of using artificial intelligence (e.g., job loss, unethical use cases)?

1	2	3	4	5

4. How important do you think the implementation of regulations and policies for the responsible use of artificial intelligence will be in the future?

1	2	3	4	5

5. How comfortable do you feel with the benefits that artificial intelligence can bring?

1	2	3	4	5

III. Perception of Artificial Intelligence as an “Autonomous Identity Structure”:

a. Rights, responsibilities, and identity recognition:

6. In your opinion, should artificial intelligence have rights and responsibilities similar to those of human beings?

1	2	3	4	5

7. In your opinion, to what extent should artificial intelligence be recognized as an entity with its own identity?

1	2	3	4	5

b. Decision-making autonomy:

8. In your opinion, to what extent should artificial intelligence have the ability to make autonomous decisions without human intervention?

1	2	3	4	5

9. In your opinion, to what extent do you think artificial intelligence could develop a form of identity or self-awareness in the future, similar to that of humans?

1	2	3	4	5

IV. Social Acceptance and Emotional Impact of Artificial Intelligence:

10. How comfortable do you feel with the idea of using artificial intelligence in the workplace?

1	2	3	4	5

11. What is your level of acceptance regarding the integration of artificial intelligence into the education system?

1	2	3	4	5

12. What is your level of acceptance regarding the integration of artificial intelligence into the arts?

1 2 3 4 5

13. What is your level of acceptance regarding the integration of artificial intelligence into transportation?

1 2 3 4 5

14. How comfortable do you feel with the idea of integrating artificial intelligence into family or couple life?

1 2 3 4 5

15. What is your level of acceptance regarding the integration of artificial intelligence into the healthcare system?

1 2 3 4 5

16. How comfortable do you feel with the idea of using artificial intelligence as a form of entertainment?

1 2 3 4 5

METHODS FOR PREVENTING AND REDUCING BURNOUT LEVELS

Prof. univ. Mihaela STOICA Ph.D.

“Dimitrie Cantemir” University of Târgu Mureș, Romania
Mihaela Stoica: mstoica96@yahoo.com

Abstract

Burnout syndrome, the disease of the 20th century, represents chronic stress in the workplace. Burnout is present in all professions. Burnout syndrome is considered a public health problem due to its increasing frequency, but primarily because of the negative consequences it has on the healthcare system. Burnout affects physical health (migraines, muscle tension, back pain, ulcers, high blood pressure, allergies, asthma, diabetes, cancer), affects cognitive abilities, leads to loss of energy, reduces workplace performance, affects or disrupts relationships with others, and generally erodes quality of life. Maslach described burnout as a gradual process of exhaustion, cynicism, and reduced social and professional involvement. It is important to understand the dimensions of burnout: mental exhaustion, which consists of a lack of emotional energy; depersonalization, where people are seen as objects; and reduced personal accomplishment, characterized by a negative view of work, low morale, and a negative opinion about one's ability to perform work. Based on these three dimensions, Maslach developed a tool to investigate the level of burnout, establishing 8 stages. The article aims to investigate the most important methods of preventing and intervening in burnout. Effective strategies for preventing burnout include: time management and task prioritization, improving work-life balance, adopting a healthy lifestyle, relaxation and stress management techniques and emotional and psychological support. The first step in addressing burnout is to help individuals recognize it where it occurs, acknowledge its symptoms and characteristics, and give it the appropriate attention for its eradication, considering the negative effects it has both on their health and on the work performed. In the field of coaching people affected by burnout, we work with a modular personal transformation concept – a personal turnaround – which consists of 6 phases: Unburdening, Detachment from the state of delusion, Discovery, Decision, Unfolding, and Detachment from the state of tension.

Keywords: burnout, Maslach test, methods for preventing, methods for reducing burnout.

Introduction

Burnout syndrome is considered a public health problem partly because of its increasing frequency, but mainly because of the negative consequences it has on the health system. Burnout syndrome (completely burning out) represents chronic stress at the workplace. Chronic stress affects physical health (migraines, muscle tension, back pain, ulcers, high blood pressure, allergies, asthma, diabetes, cancer), clear thinking, leads to loss of energy, decreases work performance, affects or disrupts relationships with others, and generally erodes quality of life [2].

Theoretical Foundation

For the first time, a general description of the phenomenon called burnout or 'occupational exhaustion' was provided by the American psychologist Freudenberger in 1974, who highlighted the states of fatigue and overwork, demoralization, and disappointment experienced by employees of psychiatric clinics [5].

The young volunteers who were working in the hospital, who at first were enthusiastic and deeply involved in what they were doing, after a year complained of fatigue, headaches, gastrointestinal disorders, and insomnia. Freudenberger described these people as 'uninspired' in contrast to the 'sparkle of the initial enthusiasm'.

Freudenberger highlighted the symptoms of burnout as: negativism, cynicism, a tendency to be inflexible, discussing in intellectual terms, belonging to specialized jargon and thereby maintaining emotional detachment, poor communication, withdrawal, and isolation. The symptom profile of burnout consists of: lack of vitality, pronounced physical weakness, frequent headaches, muscle tension in the shoulders and neck, back pain, nausea, frequent weight changes, chronic fatigue, sleep disturbances - insomnia, nightmares, a negative attitude towards oneself, others, work, and life in general, feelings of professional dissatisfaction, feelings of inferiority, a negative attitude reaching the point of dehumanizing interpersonal relationships, feelings of despair, and helplessness. Symptoms can vary in intensity, duration, and frequency.

Burnout is a response to the continuous flow of stressors or chronic stress, leading to a significant increase in physical, psychological and behavioral dysfunctions. The most common **physical symptoms** of burnout are: extreme fatigue that doesn't go away with rest, headaches, recurring migraines, muscle and bone pain, tension in the neck and shoulders, sleep disturbances - insomnia, frequent awakenings, frequent infections due to decreased immunity, digestive disorders, ulcers, irritable bowel syndrome, and a feeling of mental fog. Examples of **emotional symptoms** include irritability, nervousness, lack of motivation, a sense of inner emptiness or emotional detachment, increased anxiety, sadness or apathy, decreased self-confidence, and a feeling of uselessness. **Behavioral signs of burnout** include avoiding tasks or procrastination, absenteeism at work, decreased performance, social withdrawal, disordered eating, tendency to overeat, impulsive behavior, excessive consumption of coffee, alcohol, or tobacco, use of stimulants, nervous laughter, conflicts with others, aggressiveness and decreased interest in hobbies.

The symptoms of burnout on the organization are: absenteeism, resignations, decreased productivity, isolation, job dissatisfaction, reduced responsibility and loyalty to the company, violent behavior, tense atmosphere, interpersonal conflicts, workplace accidents, medical leave, employee turnover.

A first definition was given by Maslach for burnout, thus he defines it as a syndrome of emotional exhaustion that is characterized by fatigue, somatic symptoms, a decrease in emotional resources and the feeling that he has nothing left to offer others leading to depersonalization and the development of negative, cynical attitudes and impersonal feelings towards their clients, treating them as objects as well as lacking feelings of personal accomplishment. [1, p. 430]

Burnout is a syndrome of emotional exhaustion, depersonalization, and reduced personal accomplishment characterized by distress resulting from specific harmful factors. Emotional exhaustion refers to the experience of individuals feeling that they are operating beyond their

comfort limits. Reduced personal accomplishment refers to the tendency to see oneself as ineffective, worthless, and having a negative influence on colleagues. Depersonalization refers to the tendency to maintain distance, to see others as things or impersonal objects, and also the tendency to keep distance from them [4, p. 162].

Initially, Maslach and Jackson both, Leiter and Maslach and assumed that between the three dimensions there are direct relations, depersonalization mediated the relationship between emotional exhaustion and low personal fulfillment. Later he started to outline the idea that emotional exhaustion affects professional performance, not just through the depersonalization, but also directly (figure 1)



Figure 1. Three-dimensional model of the burnout [4, p. 598].

Implications of burnout are on the mental health and thus on the job performance.

Dominique Barbier [5, p. 270] presents four phases of burnout syndrome: idealistic enthusiasm, inefficient stagnation, a sense of frustration, and the final phase, apathy. The first phase, called idealistic enthusiasm, is characterized by an attitude more typical of a beginner who has high expectations and who over-invests in their career at an extremely high energy level; hence the notion of 'burnout.' The individual, who can no longer keep up the pace, experiences a significant drop in efficiency during this phase. The second phase is that of inefficient stagnation, where work loses its primary appeal, the praise received is seen as a joke and not stimulating, while personal demands come to the forefront, as if the individual feels deceived. The third phase is characterized by feelings of frustration, which affect our work, make us reconsider our choices while feeling unwell, so we are prone to developing physical disorders (headaches, migraines, gastrointestinal disorders, etc.), emotional disorders (anxiety, depression), and behavioral issues. The individual questions the meaning of their work, reevaluates their choices, feels unwell, and loses motivation to work. The final phase, apathy, is characterized by feelings of disappointment and insecurity, which are felt almost chronically, being frustrating, and a struggle with the need for employment, purely for economic reasons, accompanied by a devalued self-image.

The onset of burnout syndrome is influenced by certain characteristics related to the individual, as well as certain causes related to the organization.

The individual-related causes of burnout are gender – women are more predisposed, a tendency toward depression or anxiety, and the desire to do everything perfectly, which gradually depletes psycho-emotional resources. The desire to be perfect is the reason why,

paradoxically, burnout most often affects people who are good at what they do: perfectionists, responsible individuals, and those who are engaged.

Burnout from overwork occurs in people who take on too many responsibilities for a long period, either because they feel unable to say "no" or because they are driven by high performance standards. They work excessively, without real breaks, ignoring signs of fatigue, the need to rest, and their personal life, and after a while, their cognitive functions, sleep quality, and immunity are affected, leading to a persistent state of irritability. Many end up seeing a doctor when they are already in physical or mental collapse.

The organizational causes that can lead to burnout are:

- *Professional overload* – a high workload, short deadlines, deadline pressure, performance pressure, and multiple responsibilities can exceed individual resources.
- *Professional underload* – Burnout from lack of challenge occurs in situations where the employee does not feel stimulated, valued, or intellectually challenged. Repetitive jobs, monotonous tasks, and lack of opportunities for professional development can gradually lead to a deep sense of uselessness. A person affected by this type of burnout is not overworked, but rather "disconnected" from the work they do, trapped in a state of "emotional numbness" in which they no longer feel joy or interest and have no energy for professional tasks or personal activities. Lack of direction increases the risk of social isolation and anxiety.
- *Inadequate schedule* – long hours, unstable schedule, shift work.
- *Type of work*: tasks that seem insignificant or without a clear purpose, are repetitive and boring;
- *Lack of control* over work schedule, tasks, and decisions (gradually instils a sense of helplessness);
- *Job insecurity*
- *Ambiguity role* - expectations are unclear and *role conflict* - conflict between the two roles and the impossibility of setting boundaries;
- *A tense or toxic work environment* – misunderstandings / conflicts with colleagues / clients, hostile management, lack of recognition for efforts and achievements;
- *Inadequate supervision* and perception of injustice, lacking support and deprived of feedback
- *Lack of a support system* – family, friends, colleagues; managerial support is missing,
- *The imbalance between personal and professional life* – lack of sleep and free time.

Material and Method

Burnout is a serious problem, but it can be prevented and treated. Interventions for burnout must consider addressing these causes, and interventions occur at both the individual and organizational levels.

Prevention and intervention of burnout at the individual level is achieved through managing emotions - developing emotional skills, developing personal resources: resilience, optimism, self-efficacy, and a healthy lifestyle: sleep, nutrition, exercise.

In the current global situation, every small contribution can make a big difference, so a useful solution to reduce the impact of burnout is the development of emotional skills. Developing employees' emotional capacities should be a priority. Implementing programs that promote

health in the workplace has been shown to be an investment, not an expense. These programs provide a positive return, which is why it is imperative. For this reason, training programs should aim not only at developing professionals' emotional skills to prevent burnout issues, but also at promoting individual outcomes [6].

A healthy lifestyle is very important in preventing burnout. Health is our most asset. It is reason enough to treat our body properly. It is important to have and maintain a balance between sleep, work, and relaxation. The 3 eights — 8 hours of work, 8 hours of relaxation, and 8 hours of rest — have long lost their relevance [2].

Interventions for individual-level burnout include: organizing your personal workspace, engaging in stress-relieving activities during free time (hobbies are essential), developing skills and behaviors, stress management skills (developing assertiveness, improving positive communication with others, learning how to say no, identifying and resolving conflicts, and learning problem-solving and decision-making methods), learning relaxation techniques (Jacobson's progressive relaxation method, Schultz's autogenic training), developing a healthy lifestyle, establishing and maintaining adequate social support, building self-confidence, and time management.

Organizational-level burnout prevention strategies consist of creating a work environment suitable in terms of job characteristics (job design), work relationships (organizational climate), organizational structure, establishing a healthy organizational culture, and employee training programs.

At the organizational level [3, p. 12) training programs are organized: Conflict management, Time management – task prioritization, delegation, Organizational stress management, Work / life balance policies, Creating a support group, Coaching, mentoring.

Methods for intervening in burnout are primary interventions to reduce organizational stressors, the secondary intervention that deals with the rapid detection and management of experienced stress and tertiary intervention focuses on the treatment, rehabilitation, and recovery process.

Primary intervention includes actions to modify or eliminate inherent sources of stress in the work environment, reducing the negative impact on the employee. Strategies for reducing stress factors: redesigning tasks and the work environment, establishing flexible schedules, analyzing roles and objectives, involving the employee in the career development process, providing social support, giving rewards, building a united team.

Secondary intervention focuses on the rapid detection and management of experienced stress by improving stress management skills (cognitive coping skills, time management, lifestyle changes, assertiveness development). This type of intervention deals with the consequences of stress, not its sources; the organization will not change and will continue to be dominated by stress, which is why the individual will develop their stress resilience.

Tertiary intervention focuses on the treatment, rehabilitation, and recovery process of those who have suffered or are suffering from serious health problems caused by stress by providing counselling services for personnel (divorce, bereavement, etc.) and professional issues. It has been proven that counselling services are effective in improving employees' well-being and are cost-effective.

Conclusion

About burnout, I have two news one bad and one good. The bad news is Maslach has shown that the phenomenon of burnout can affect anyone in any profession, and the good news is that burnout is treatable. I think it is very important to diagnosis burnout and to take measures to combat him. Preventing and treating burnout should be addressed not only at the individual level but also at the organizational level.

The study shows what is important is to diagnosis burnout and intervention in burnout in order not to affect the work. The article emphasizes the importance of organizations being involved in preventing and treating burnout, and consequently in ensuring the health and well-being of employees. Managers need to realize that physically and mentally healthy employees ensure the success of the organization and should invest time and money in measures taken to diagnose and treat burnout.

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ANALYSIS OF COPING STRATEGIES AND THE PSYCHO EMOTIONAL IMPACT PARENTS OF CHILDREN WITH DISABILITIES

Prof. univ. Mihaela STOICA Ph.D.¹, Dana Mariana CEZAR²

¹*“Dimitrie Cantemir” University of Târgu Mureș, Faculty of Psychology, Romania*

²*Rehabilitation center for children with disabilities, Romania*

Correspondent: Mihaela Stoica: mstoica96@yahoo.com

Abstract

For parents, the news of a diagnosis of a “disability” in their own child can be a heavy blow, accompanied by stress, questions, and often emotional decline, which can turn into constant emotional pressure. Behind every diagnosis is a child with special needs, but also a parent who fights every day against fatigue, fear, guilt, hope, and the strength to carry on. Social support and the ways in which parents manage their emotions and daily challenges through various coping strategies play a crucial role in their adaptation to the difficulties of raising a child with disabilities. This paper aims to present the results of a personal research study that investigated the psychological and emotional impact experienced by parents, in relation to levels of anxiety, depression, stress, and their perception of quality of life. The study was conducted on a sample of parents raising children with various types of disabilities, focusing on the relationship between perceived social support and coping strategies — both adaptive and maladaptive — and how these variables correlate with their emotional well-being and their overall evaluation of life quality. The research instruments used were a series of scientifically validated questionnaires: DASS-21R (Depression Anxiety Stress Scales – Revised), which allows the assessment of the severity of depression, anxiety, and stress symptoms, initially developed by Lovibond in 1995 and later revised by Henry & Crawford in 2005; CERQ (Cognitive Emotion Regulation Questionnaire), an instrument designed by N. Garnefski, V. Kraaij, and P. Spinhoven in 2001, which measures how individuals manage their negative emotions, such as self-blame, acceptance, rumination, positive refocusing, refocusing on planning, positive reappraisal, putting into perspective, catastrophizing, and blaming others. WHOQOL-BREF, developed by the World Health Organization to measure quality of life, which assesses four main domains: physical health, psychological state, social relationships, and the surrounding environment of participants and MSPSS (Multidimensional Scale of Perceived Social Support), developed by Zimet and colleagues in 1988, which measures perceived support from three sources: family, friends, and significant others. As specialists, in order to truly support the child, we must start by understanding and supporting the parent.

Keywords: parents, disability, stress, anxiety, depression, coping, social support

Introduction

Parents of children with disabilities consistently face significantly higher levels of stress and emotional strain compared to parents of typically developing children, and international research frequently reports a diminished quality of life within this population [2, 4]. Over the past two decades, studies have shown that when caregiving demands are chronic and intense, emotional burden increases substantially, affecting psychological health and family functioning [6, 15]. Recent meta-analyses converge on the same conclusion: anxiety, depression, and parental stress are systematically higher among these parents, with variations influenced by disability severity, financial resources, and available social support [13, 14].

Large-scale studies emphasize the central role of social support and coping strategies. Adequate family support helps reduce stress and improve emotional adjustment [7, 9], whereas maladaptive cognitive strategies such as catastrophizing, rumination, or self-blame consistently correlate with higher levels of anxiety and depression [8]. Conversely, adaptive strategies such as positive reappraisal or acceptance are associated with greater emotional stability and enhanced quality of life [12]. These findings align with the transactional model of stress, which conceptualizes coping as a dynamic process influenced by cognitive appraisal and internal and external resources [5]. Instruments such as the CERQ allow detailed analyses of cognitive emotion regulation strategies, while standardized measures of mental health and quality of life provide an integrated perspective on the psychological impact of caring for a child with disabilities [11].

Based on this theoretical and empirical background, the present study aims to investigate the relationships among cognitive emotion-regulation strategies, perceived social support, and the emotional status of parents of children with disabilities. The following hypotheses were formulated: maladaptive strategies are associated with higher levels of stress, anxiety, and depression; adaptive strategies contribute to more efficient emotional regulation; perceived social support has a protective effect on mental health; and quality of life is significantly influenced by the level of perceived support. By integrating theoretical perspectives with empirical data, the study contributes to understanding the psychological mechanisms involved in parental adjustment and highlights factors that may guide the development of effective interventions to enhance family well-being.

Research Methodology

Research Objectives

The general objective of this study was to identify the psycho-emotional implications experienced by parents of children with disabilities, in relation to the coping strategies used to manage daily challenges.

Specific objectives are:

- O1: To evaluate levels of anxiety, depression, and stress.
- O2: To identify cognitive coping strategies.
- O3: To measure perceived social support.
- O4: To evaluate parents' quality of life.
- O5: To analyze the relationship between stress, coping, and social support.

Research Hypotheses

Research hypotheses are:

H1: It is assumed that there is a positive correlation between parental stress and the use of maladaptive coping strategies among parents of children with disabilities.

H2: It is assumed that there is a negative correlation between perceived social support and anxiety levels among parents of children with disabilities.

H3: It is assumed that there is a negative correlation between perceived social support and depression scores.

H4: It is assumed that parents who use adaptive coping strategies obtain lower depression scores.

H5: It is assumed that there is a positive correlation between perceived social support and quality of life.

H6: It is assumed that parents reporting lower quality of life make more frequent use of maladaptive coping strategies.

H7: It is assumed that there is a positive correlation between the use of maladaptive coping strategies and anxiety levels among parents of children with disabilities.

H8: It is assumed that there is a positive correlation between the use of maladaptive coping strategies and depression scores among parents of children with disabilities.

Participants

The study included 42 parents of children with disabilities, aged 22 to 57. The sample was predominantly female (38 mothers, 4 fathers). Participants represented diverse family backgrounds, and all were primary caregivers for at least one child diagnosed with a disability. Participation was voluntary.

Materials and Method

Four internationally validated psychometric instruments were used:

CERQ – Cognitive Emotion Regulation Questionnaire [3]

DASS-21R – Depression, Anxiety, Stress Scales, Lovibond & Lovibond, 1995; revised by Henry & Crawford, 2005

MSPSS – Multidimensional Scale of Perceived Social Support [16]

WHOQOL-BREF – Quality of Life Assessment [11]

Data analysis employed Pearson correlation coefficients to examine relationships among variables.

Results

The descriptive analyses show that parents predominantly used adaptive coping strategies. The most frequently used strategy was "Refocusing on Planning" ($M = 16.43$; $SD = 3.09$), followed by "Positive Reappraisal" ($M = 15.83$; $SD = 4.40$) and "Acceptance" ($M = 14.93$; $SD = 3.63$). Maladaptive strategies such as "Catastrophizing" ($M = 9.62$; $SD = 3.10$) and "Self-Blame" ($M = 7.74$; $SD = 3.28$) were used less frequently, with "Blaming Others" being the least used ($M = 6.17$; $SD = 2.12$).

Table 1. Analysis of Coping Strategies

Analysis of Coping Strategies					
	N	Minimum	Maximum	Mean	Std. Deviation
Self-blame	42	4	16	7.74	3.284
Acceptance	42	4	20	14.93	3.632
Rumination	42	4	20	11.33	4.171
Positive refocusing	42	4	20	12.93	5.172
Planning refocusing	42	8	20	16.43	3.093
Positive refocusing	42	4	20	15.83	4.400
Putting into perspective	42	4	20	14.43	4.295
Catastrophizing	42	4	19	9.62	3.100
Blaming others	42	4	12	6.17	2.117
Valid N (listwise)	42				

DASS-21R results indicated moderate levels of anxiety ($M = 9.33$; $SD = 7.84$), somewhat elevated depression ($M = 11.24$; $SD = 9.09$), and stress ($M = 9.57$; $SD = 9.87$), showing considerable emotional strain among participants (table 2).

Table 2. Psychological and Emotional Symptoms

Psychological and Emotional Symptoms					
	N	Minimum	Maximum	Mean	Std. Deviation
Anxiety	42	0	38	9.33	7.848
Depresion	42	0	38	11.24	9.095
Stress	42	0	48	9.57	9.873

Perceived social support was generally high for family ($M = 6.09$; $SD = 1.26$) and significant others ($M = 6.32$; $SD = 0.88$), while friend support was moderate ($M = 5.16$; $SD = 1.33$). The total score ($M = 70.26$; $SD = 11.64$) reflects an overall favorable perception of social networks. (table 3)

Table 3. Perceived Social Support (MSPSS

Percepția sprijinului social					
	N	Minimum	Maximum	Mean	Std. Deviation
Family	42	2	7	6.09	1.260
Significant others	42	3	7	6.32	.878
Friends	42	2	7	5.16	1.334
Total suport score	42	31.00	84.00	70.2619	11.64110

Quality of life assessed through WHOQOL-BREF ranged from moderate to high: physical domain ($M = 21.29$), psychological ($M = 21.67$), social relationships ($M = 11.29$), and environment ($M = 28.90$), with an overall mean score of 83.14 ($SD = 12.02$). (table 4).

Table 4. Quality of Life

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Psyhical health	42	17.00	26.00	21.2857	1.82511
Psychological health	42	15.00	27.00	21.6667	3.89287
Social relationships	42	6.00	15.00	11.2857	2.44237
Environment	42	23.00	39.00	28.9048	4.83286
WHOQOL-BREF total	42	66.00	107.00	83.1429	12.01944

The Pearson correlation analysis allowed for the verification of the proposed hypotheses. The results confirm H1, indicating a significant positive correlation between parental stress and the use of maladaptive coping strategies ($r = 0.421$; $p = 0.005$). Perceived social support correlates negatively with both anxiety ($r = -0.455$; $p = 0.002$), confirming H2, and depression ($r = -0.380$; $p = 0.013$), supporting H3. H4 is also confirmed, as adaptive coping strategies show a significant negative association with depression ($r = -0.391$; $p = 0.011$). The positive correlation between perceived social support and quality of life ($r = 0.477$; $p = 0.001$) supports H5. Hypothesis H7 is likewise confirmed, with maladaptive strategies correlating positively with anxiety ($r = 0.378$; $p = 0.014$), as well as H8, which concerns their relationship with depression ($r = 0.330$; $p = 0.033$). The only hypothesis not supported by the data is H6, as no significant relationship was identified between quality of life and the use of maladaptive coping strategies ($r = 0.049$; $p = 0.757$).

Conclusion

The results indicate that perceived social support and coping strategies play a significant role in the psychological well-being of parents of children with disabilities. Support from family, friends, and significant others is associated with lower levels of anxiety and depression and with a higher quality of life. Adaptive coping strategies contribute to reduced depressive symptoms, whereas maladaptive strategies—such as rumination or catastrophizing—increase vulnerability to anxiety, depression, and stress. These findings highlight the importance of strengthening functional coping strategies and improving access to social support networks as essential pathways to maintaining emotional balance and enhancing the well-being of parents caring for children with disabilities.

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LANGUAGE LEARNING ANXIETY IN THE ENGLISH CLASSROOM – A QUALITATIVE APPROACH

Lecturer Anca NEMEȘ Ph.D., Assoc. Prof. Cristina BERARIU, Ph.D.

“Dimitrie Cantemir” University of Târgu Mureș, Faculty of Psychology, Romania
Correspondent: Anca Nemeș, a.m.nemes@gmail.com

Abstract

This study investigates the prevalence and impact of language learning anxiety among college-level English as a Second Language (ESL) students, using the Foreign Language Classroom Anxiety Scale (FLCAS). Sixty undergraduate participants from diverse backgrounds completed the FLCAS at the onset of the academic year, providing baseline data on their emotional responses to English language learning. The research aims to quantify the degree of anxiety, explore its primary sources, and assess how anxiety correlates with students' language performance, engagement, and academic motivation. Initial review of the FLCAS items highlights common factors such as communication apprehension, social anxiety, and fear of negative evaluation. By analysing these dimensions, the study seeks to map anxiety profiles in the classroom context and identify groups most at risk of adverse academic outcomes. Anticipated findings will offer valuable insights into the role of anxiety in shaping learners' attitudes and behaviour and inform teaching practices aimed at creating a more supportive and effective classroom environment. The study's outcomes are expected to contribute to the development of targeted interventions and curricular adjustments that reduce anxiety and enhance language acquisition for college students.

Keywords: ESL, language learning, anxiety, academic motivation, teaching method

Introduction

Foreign language classroom anxiety (FLCA), conceptualized by Horwitz et al. (1986), is a context-specific form of anxiety, distinct from general trait anxiety due to its ties to communication apprehension, fear of negative evaluation, and test anxiety in language learning settings. The 33-item FLCAS, with a level of reliability measured at $\alpha > 0.90$, measures FLCA and reveals its negative correlations with proficiency across skills like speaking and listening. Meta-analyses confirm moderate to strong inverse links between FLCA and achievement, alongside impacts on motivation and well-being [1].

Prevalent among college ESL students, FLCA manifests more acutely in oral skills, exacerbated by online or evaluative contexts. Factors such as proficiency level, age, and prior experiences amplify anxiety, with beginners often reporting higher levels than advanced learners. Longitudinal studies using FLCAS pre- and post-tests track reductions through various types of educational interventions, highlighting FLCA's versatility [2].

This study reports pretest results from the Foreign Language Classroom Anxiety Scale (FLCAS) administered to 50 first-year college students in Romania, revealing a mean score of 52.2 (SD = 25.14), with 76% of participants reporting low anxiety. Notable differences emerged

by English proficiency level, with beginners ($n=22$, $M=72.27$, $SD=17.95$) showing substantially higher anxiety than advanced learners ($n=28$, $M=36.43$, $SD=17.61$, suggesting proficiency might be a key anxiety driver.

Participant Demographics

The study sample consisted of 50 first-year psychology students enrolled in Dimitrie Cantemir University of Târgu Mureș, Romania and following an optional 4-semester ESL course. The participants who pursue the ESL course may opt to join one of two groups, according to proficiency, which is why the research sample was also divided in just two subgroups: beginners (A1 to B1) and advanced (B2 to C2). The gender distribution of the sample was 88% female and 12% male, reflecting the natural gender distribution of psychology cohorts. The sample's mean age was 31.24 years, with the youngest participant being 18 and the eldest 50 years old. This fact supported our decision to split the sample into two age subgroups, namely below 30 and above 30 years of age. Participants had studied English for an average of 8.24 years, with 44% having opted to join the beginner group and 56% going for the advanced group.

Descriptive Statistics

The FLCAS 33 item scale was administered in the second week of the first semester, with the plan to re-test in the last week of the academic year and compare the resulting means, looking for any increases in the overall score, as well as a potential mitigation of the score discrepancies between subgroups.

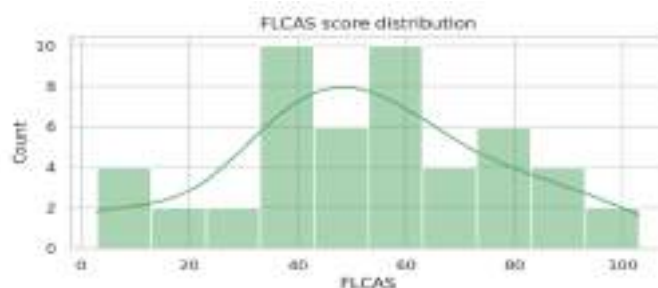


Fig. 1. Overall FLCAS results

The mean FLCAS score obtained by the participant sample was 52.2 ($SD = 25.14$), indicating moderate anxiety levels overall. Categorically, 76% exhibited low anxiety and 24% medium anxiety, with none of the participants reporting a high level of language learning anxiety. These pretest scores provide a baseline for end-of-year retesting to assess educational intervention effects.

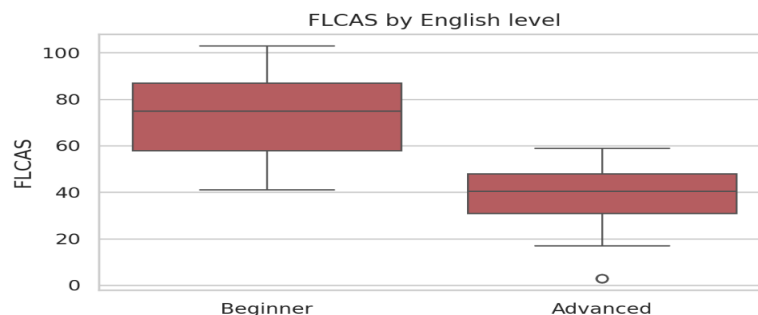


Fig. 2. Differences by proficiency level

Beginner students displayed significantly higher anxiety ($M = 72.27$, $SD = 17.95$) than advanced students ($M = 36.43$, $SD = 17.61$). Proficiency seems to therefore reveal itself as a strong predictor in this sample. Age was another variable which positively correlated with FLCAS scores (Pearson's $r = 0.372$, $p = 0.008$), accounting for 13.8% of variance, suggesting older learners reported higher anxiety.

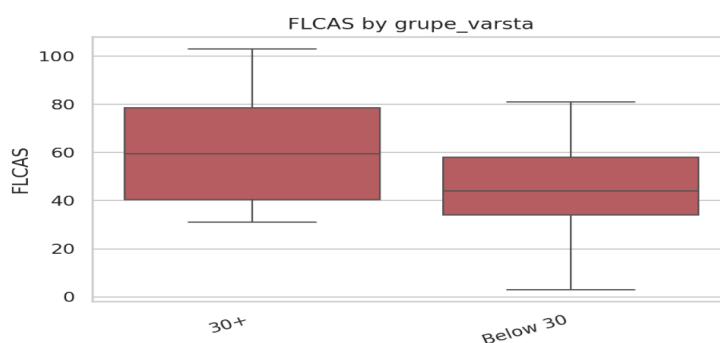


Fig. 3. Differences by age groups

The graph above depicts FLCAS scores by age group, showing higher median scores and greater variability for the 30+ year group ($n=24$) compared to those below 30 ($n=26$), consistent with the moderate positive correlation ($r=0.372$, $p=0.008$) between age and anxiety.

The learning experience variable showed no categorical difference with regard to anxiety scores. We decided to split this widely varying variable into four subsets, roughly corresponding to one educational cycle. Thus, subset 1 comprised participants who had studied English for a maximum of 4 years, subset 2 for a maximum of 8 years, and so on. The "years of study" variable has a median of 8 years and ranges from 2 to 16 years, meaning many students are not "true beginners" in exposure even if their current level may be beginner.

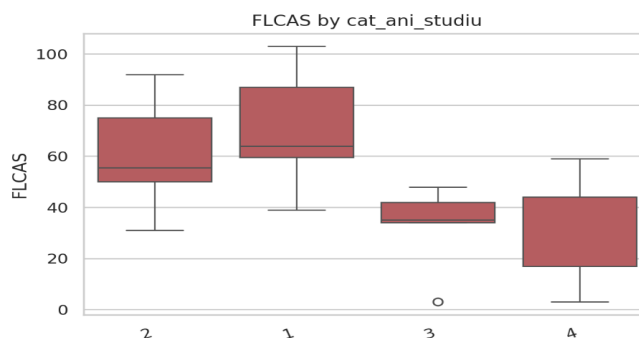


Fig. 4. Differences by study experience

Even within the same level label, learners do have very different histories (many years of low-quality exposure vs fewer years of intensive study). That may affect anxiety through perceived gaps, prior negative experiences, fossilized errors, or confidence built from repeated exposure. This is why study experience can be partly independent of level.

The sample's gender distribution reflects the reality of psychology as a field of study currently more sought after by female students, albeit resulting in an imbalanced research sample in this respect, with only n=6 males to n=44 female participants.

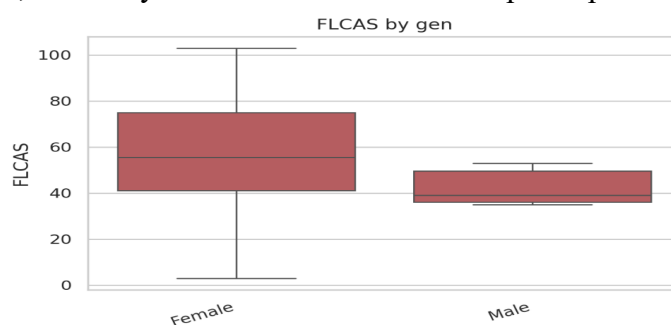


Fig. 5. Differences by gender

Gender differences were untestable due to the small male subsample. However, gender differences in reported anxiety do sometimes show up due to socialization around evaluation/performance, classroom participation norms, and comfort with making mistakes publicly. Given a larger and more balanced sample with regard to gender, this variable might still prove to be a plausible factor to consider.

Conclusion

This review of the FLCAS initial results highlights common factors such as communication apprehension, social anxiety, and fear of negative evaluation. By analyzing these dimensions, the study seeks to map anxiety profiles in the classroom context and identify groups most at risk of adverse academic outcomes. After the next phase of testing is complete, statistical analysis will be utilized to examine relationships between anxiety levels and variables including proficiency, age, and gender. The findings we anticipate will offer valuable insights into the role of anxiety in shaping learners' attitudes and behaviour and inform teaching practices aimed at creating a more supportive and effective classroom environment. The study's outcomes are expected to contribute to the development of targeted interventions and curricular adjustments that reduce anxiety and enhance language acquisition for college students.

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THE INFLUENCE OF CHILDHOOD TRAUMA ON ADULT LIFE

Asist. Prof. Cornelia FARCAȘ Ph.D., MSc student Valentina-Denisa CÎNDEA-PÎRVULESCU

*"Dimitrie Cantemir" University of Târgu Mureș, Faculty of Psychology, Romania
Correspondent: Cîndea-PîrvulescuValentina-Denisa: vali.pirvulescu@yahoo.com*

Abstract

Childhood traumas guide all of our daily life interactions and behaviour more than we can imagine. In difficult moments, unhealed wounds of our inner child surface that lead us to impulsive reactions and behaviours that are sometimes inappropriate or unhealthy both for us and for others in our interpersonal relationships with them. This topic has gained a lot of momentum in recent years, with various studies being carried out on the issue of childhood trauma. I chose to structure the chosen theme in two chapters, the first having seven subchapters and the second only two subchapters. Among the most damaging and common forms of trauma are emotional, physical and sexual neglect and abuse, and the loss of the one or more parents through death or divorce. For a quality life from a personal, emotional and social point of view and a good state of health it is essential to turn to ourselves with the courage to look inside, to our inner child and to call on the tools we have to cope with the challenges and difficult situations in our lives. More and more tools appeared including courses, books, workshops, retreats on the topic of self-discovery, accessing inner resources and healing traumas. Having access to information about what trauma is, what caused it, what attachment style we developed, whether we developed any of the 5 wounds that prevent us from being ourselves, how we relate to trauma and current difficult situations in our lives, what defines mechanisms we use, it is quite easy for us to inform ourselves and take action to discover ours and work with us to reach our best version.

Keywords: trauma, childhood, abuse, dysfunctional environment, attachment style, emotional regulation

Theoretical Considerations

Trauma is a wound manifested by a lasting rupture within the self due to difficult or painful events. It is about what happens inside the person as a result of a painful event, not the event itself.

Childhood traumas can generate anxiety, depression, personality disorder, identity disorder, post-traumatic stress disorder, low self-esteem, self-sabotage by unconsciously choosing partners in romantic relationships similar to the parent who hurt us the most, emotional dependence on others or on the validation of others and last but not least the development of an insecure attachment style.

The main forms of childhood traumatization are: Emotional neglect; Physical negligence; Emotional abuse; Physical abuse; Sexual abuse; Divorce or separation of parents, which also involves the "loss" of one of the parents; Death of one or both parents; Domestic violence.

Classification of Types of Traumas According to Franz Ruppert

1. Identity trauma occurs in the first months of life, when the child feels unwanted, unwelcome with positive and calm experiences.
2. For example, being separated from the mother early or giving birth to a child against the mother's desire to have it
3. The love trumpet appears as a wish for the rupture produced in the relationship between mother and child, so the child no longer feels the connection with the mother to be one of security, stable and balanced and his psyche is invaded by feelings of helplessness, plot, vulnerability.
4. Sexual trauma is the invasion of a person's bodily space for sexual purposes, i.e. sexual harassment, rape or incest. As a result of one of these situations, self-disconnection occurs, numbness and then denial ("didn't that happen" or "did this really happen"?)
5. Trauma of becoming an aggressor: in this type of trauma the person harms himself and hurts others. It is characterized by disconnecting from our capabilities at such a high level that we end up using them against ourselves.

The Inner Child and Attachment

The inner child represents that immature, hurt and fearful part of us that carries our emotional suffering and less present or healthy reactions, which the adult self-manifests when problems or unpleasant situations in childhood are activated.

Our inner child has memorized and stored all the unpleasant or bad events that have happened, and they are as real emotionally as they were then.

The things that happened to us in childhood tend to have a greater impact on us than the things that happen to us in adulthood. These unpleasant events are especially those that occur in closer relationships such as parents, grandparents or caregivers.

When we were children, our brains were not fully developed and we perceived the things that happened to us to be extremely important, but as we become adults, increasing our ability to see the world, we believe that what happened to us in childhood is not of great importance. The first years of life are essential because it is then that the structure of the brain with neural networks and connections is formed.

The attachment style is closely related to childhood and the affective connections created during childhood. The attachment style in adulthood is determined by the way we were treated and cared for in childhood, if our parents were present at our needs, available to us then we are predisposed to have a secure attachment style, if instead their attention and availability was inconsistent the chances of developing an anxious attachment style are high, And if they were emotionally absent, did not offer availability and affectivity, then the attachment style we can develop is the avoidant one.

Children who have been physically abused or neglected are more likely to develop an insecure or anxious attachment compared to those who have not been physically abused. Those who are severely abused develop a disorganized attachment style.

Physical abuse in childhood develops the risk of entering into a conflictive romantic relationship, both as an aggressor and as a victim.

When we were children, our brains were not fully developed and we perceived the things that happened to us to be extremely important, but as we become adults, increasing our ability to see the world, we believe that what happened to us in childhood is not of great importance. The

first years of life are essential because it is then that the structure of the brain with neural networks and connections is formed.

The child cannot judge the parent or the parent's behaviour by labelling it as bad or good, but considers that the parent is not wrong, only he himself is the problem. The child does almost anything to be liked by his parent.

The experiences of the first 2 years of life are deeply rooted in the memory of the body and in our subconscious.

Children have four fundamental psychic needs: the need for belonging, the need for autonomy and control, the need to satisfy pleasure or avoid unpleasantness, and the need for recognition.

It is important to remember that the need for attachment is not only present in children and does not end once we get out of diapers, it continues to motivate us throughout life, is an integrated part of human behaviour, is part of us.

Unhealthy attachments can have repercussions even in adult physiology.

Childhood Traumas Can Develop in the Following Contexts

1. Child abuse: emotional, physical or sexual.
2. Trauma in the intra-family environment: substance abuse of parents, separation or divorce of parents, suicidal attempts or thoughts among parents, presence of mental illness or mental disorder among parents, domestic violence, a family member in prison.
2. All these traumas refer to the parents or caregivers, the people who live with the child and are in charge of his care and upbringing.
3. Neglect of the child, failure to meet the basic physical or emotional needs of the child, abandonment of the child.

Forms of Prevention of Mental Traumatization

1. That the traumatic event does not occur, that it does not become harmful to the person, within the limits of the possibilities. For example, to contribute to the reduction of poverty situations; Let's avoid normalizing mental, physical or sexual abuse.
2. To develop human resources and capacities, depending on the age at which the traumatization occurs

Prevention involves reducing the risk of developing situational factors that threaten physical and mental integrity and developing management resources in the event of trauma.

Meta-analytical Study

In 2016, a study was carried out by Iulia Ciorbea and Anamaria Voinea, with the parents' consent on children's participation in psychological research (entitled *Adverse events in childhood and resilience strategies in adolescents*). The ACE and RASP Adverse Childhood Experience Questionnaire, the Resilience Profile and Aptitude Skills were used as tools.

The research was carried out on several 332 participants, 163 girls and 169 boys between 16-20 years old.

Among the results obtained, it was discovered that: the adolescent finds in creativity the way to combat the effects of adverse events by detaching himself and focusing on creative activities; positive and negative experiences significantly determine adolescents' outcomes on their

resilience; The effects of toxic stress resulting from childhood trauma may or may not be immediately visible.

Research Methodology

Research Sample

We chose the case study method, applied to 5 subjects, aged between 25 and 32 years. The subjects are from Mureş County, from the city of Târnăveni, 2 of them currently living abroad.

Investigation tools

We applied the following tools to each subject:

- Rosenberg Scale for Self-Esteem Assessment
- Adult Attachment Type Scale (AAS) to identify attachment style
- CTQ-Childhood Trauma Assessment Questionnaire, which evaluates 5 types of maltreatment and also has a 3-item scale corresponding to the minimization/denial of some answers.

Conclusions and Practical Implications

For the most part, what the subjects described in the informal interview as dysfunctional behaviour in the family, which they went through in interaction with parents or caregivers, also coincided in the results of the questionnaires, especially in the Questionnaire for the Assessment of Childhood Trauma. The subjects of case studies no. 1, 2, 3 and 5 have in common the abandonment of the father in childhood. And the subjects of studies 2, 3, 4 and 5 have emotional abuse in common.

The objectives of the research were achieved, the investigations showed clear links between childhood traumas and the self-esteem that a person develops in adulthood, attachment style and depression, anxiety or another disorder that may be the result of unhealed adverse childhood experiences.

The subject of the case study no. 4 of the study, given the forms of mistreatment she went through in childhood and depression developed in adulthood, and the fact that she developed a high self-esteem and secure attachment style, is the result of constant work with herself and is proof that we can heal our traumas. Even if we don't cure them completely, we may not let them dictate our behaviour and the way we live our lives.

Healing childhood traumas is a deep work with the self, which does not mean that those behavioral abnormalities, which parents and caregivers have presented, are forgotten or no longer have any effect on us, it just means that we manage to look at them consciously, that we can be vulnerable in situations of mourning or loss because we know that they are normal stages, that we can recognize an emotion, that we can manage anger through a lot of exercise, that sometimes we manage to manage an emotion effectively, other times it's not okay.

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THE INFLUENCE OF ARTIFICIAL INTELLIGENCE ON OCCUPATIONAL STRESS

**Ms.C. Stud. Maria-Eugenia MARTINOVICI (SUCIU)¹, Assoc. Prof./Vice-rector
Valentin-Florin CIOTEA Ph.D.², Maria CIOTEA³**

“Dimitrie Cantemir” University of Târgu Mureș, Romania

¹*Faculty of Psychology;*

²*Faculty of Law;*

³*Student at UMFST George Emil Palade, Târgu Mureș, România*

Corresponding author: Valentin-Florin Ciotea: cioteavf@gmail.com

Abstract

The rapid integration of Artificial Intelligence (AI) technologies into the workplace has transformed the nature of work, communication, and decision-making processes. While AI promises efficiency, precision, and automation of repetitive tasks, it also raises significant questions about its impact on employees' psychological well-being and occupational stress. This study explores the relationship between AI adoption and levels of professional stress among employees across various sectors. The research aims to identify both the positive and negative effects of AI on work-related stress, including aspects such as job security, workload, autonomy, and interpersonal relationships. Through a mixed-method approach that includes a structured questionnaire distributed among employees, this research seeks to assess perceptions, attitudes, and coping mechanisms associated with AI-driven changes in the workplace. Quantitative data will provide statistical insights into the correlation between AI exposure and perceived stress levels, while qualitative feedback will help uncover underlying concerns and adaptive strategies used by employees. Preliminary expectations suggest a dual effect: while AI may reduce stress by automating monotonous tasks and enhancing productivity, it may also increase anxiety due to fears of job displacement, loss of control, and skill obsolescence. Understanding these dynamics is essential for organizations aiming to implement AI technologies responsibly, ensuring employee well-being and long-term job satisfaction. The findings of this study are expected to contribute to the growing body of literature on the human implications of technological advancement, offering practical recommendations for employers, policymakers, and mental health professionals on managing occupational stress in the age of artificial intelligence.

Keywords: artificial intelligence, occupational stress, employee well-being, job automation, workplace adaptation

Introduction

The accelerated integration of artificial intelligence (AI) into contemporary workplaces has become one of the defining features of the current digital transformation. AI-driven systems are increasingly used to automate routine tasks, support decision-making, analyze large volumes of data, and enhance organizational efficiency. While these technologies promise substantial benefits for productivity and performance, they also reshape the psychological and social

dimensions of work, raising important questions about their impact on employees' well-being and occupational stress.

Occupational stress is a well-documented phenomenon, commonly defined as a response to perceived imbalances between job demands and the resources available to meet them. In modern work environments, stress is no longer generated solely by workload or time pressure, but also by continuous technological change, skill obsolescence, and uncertainty regarding professional roles. The introduction of AI amplifies these dynamics by altering task structures, redistributing responsibilities between humans and machines, and challenging traditional notions of control, autonomy, and expertise at work.

From an employee perspective, AI represents a source of both opportunity and concern. On one hand, AI applications can reduce stress by automating repetitive activities, improving workflow efficiency, and allowing workers to focus on more complex or creative tasks. On the other hand, AI may contribute to increased anxiety through fears of job displacement, reduced transparency in algorithmic decision-making, and perceived loss of control over work processes. These contrasting effects underline the ambivalent nature of AI as both a potential stress buffer and a stressor.

Existing research highlights that employees' responses to AI are strongly influenced by contextual factors such as digital competence, organizational culture, access to training, and perceived organizational support. When AI is introduced without adequate communication, training, or ethical guidance, it may intensify technostress and resistance to change. Conversely, transparent implementation strategies and supportive environments can foster trust, acceptance, and psychological safety among employees.

Despite growing scholarly interest in AI and the future of work, empirical studies focusing on employees' subjective experiences of AI-related stress remain limited, particularly in non-technical occupational contexts. Understanding how employees perceive AI and how these perceptions relate to occupational stress is essential for developing sustainable and human-centered approaches to technological adoption.

Within this framework, the present study aims to explore the influence of artificial intelligence on occupational stress among employees by examining their perceptions, concerns, and adaptive responses to AI use in the workplace. By focusing on the human dimension of AI integration, this research seeks to contribute to the broader discourse on balancing technological innovation with employee well-being and long-term organizational resilience.

Theoretical Considerations

Occupational stress has long been conceptualized as a psychological and physiological response arising when work-related demands exceed an individual's perceived resources and coping capacity (Lazarus & Folkman, 1984). In contemporary organizations, this imbalance is increasingly shaped by rapid technological change, which introduces new demands related to continuous learning, adaptability, and digital competence. Artificial intelligence (AI), as a transformative technology, has become a central factor in redefining both work processes and employee experiences, with significant implications for occupational stress.

Recent literature emphasizes the dual role of AI in the workplace. On one hand, AI systems can function as stress-reducing tools by automating repetitive and cognitively demanding tasks, supporting decision-making, and improving efficiency [1], [2]. By reallocating routine activities to intelligent systems, employees may experience reduced workload and increased opportunities for engaging in meaningful and creative work. This perspective aligns with job

design theories that associate higher autonomy and task significance with lower stress levels and greater job satisfaction.

On the other hand, a growing body of research highlights the emergence of AI-related technostress. Technostress refers to the strain induced by the use of advanced digital technologies and is commonly associated with factors such as complexity, uncertainty, and constant connectivity [3]. In the context of AI, technostress is intensified by the opacity of algorithmic processes, often described as the “black box” problem, which limits employees’ understanding of how decisions are generated [4]. Reduced transparency may undermine trust in AI systems and contribute to feelings of loss of control, a key predictor of occupational stress.

Job insecurity represents another critical theoretical dimension in the relationship between AI and occupational stress. Recent studies indicate that employees may experience heightened anxiety due to perceived risks of task automation or job displacement, even when actual job loss is unlikely [5], [6]. Such perceptions can negatively affect psychological well-being and increase stress levels, particularly in organizations where communication about AI implementation is limited.

Ethical and organizational factors further shape employees’ stress responses to AI. Concerns related to data privacy, surveillance, algorithmic bias, and accountability have been shown to contribute to emotional strain and resistance toward AI adoption [7], [9]. Conversely, recent evidence suggests that organizational support, participatory implementation strategies, and continuous training can mitigate AI-related stress and foster positive attitudes toward technology [8], [10].

Overall, contemporary theoretical perspectives converge on the idea that the impact of artificial intelligence on occupational stress is not technologically deterministic. Rather, it emerges from the interaction between AI-driven job demands, individual capabilities, and organizational contexts. Understanding this interaction is essential for designing human-centered AI systems that enhance performance while safeguarding employee well-being.

Research Methodology

This study adopted a quantitative, cross-sectional research design to examine the perceived influence of artificial intelligence (AI) on occupational stress in contemporary work environments. A survey-based approach was selected as it allows for the systematic collection of standardized data from a relatively large number of participants, facilitating the analysis of patterns in perceptions, attitudes, and experiences related to AI use at work.

A. Participants and Sampling

The target population consisted of employees from diverse occupational backgrounds, reflecting the widespread penetration of AI across multiple sectors. The final analytical sample consisted of 247 respondents, in line with the research design assumptions. Participation was voluntary, and respondents were recruited through online distribution channels, including professional networks and institutional communication platforms. No inclusion criteria related to age, gender, or job position were imposed, allowing for a heterogeneous sample that enhances the ecological validity of the findings.

B. Research Instrument

Data was collected using a structured questionnaire specifically developed for this study. The instrument comprised 15 closed-ended items measured on a five-point Likert scale, where 1 indicated *strongly disagreement* and 5 indicated *strongly agree*. The items were designed to capture multiple dimensions relevant to the research objectives, including perceived usefulness of AI, understanding and trust in AI systems, AI-related stress and anxiety, job insecurity concerns, perceived loss of control and transparency, workload changes, adaptability, and organizational support.

The questionnaire was preceded by an informed consent section outlining the purpose of the study, the voluntary nature of participation, and the anonymous handling of data. No personally identifiable information was collected, ensuring full compliance with the General Data Protection Regulation (GDPR).

C. Data Collection Procedure

The questionnaire was administered online using a secure digital platform. Participants were able to complete the survey at their convenience, minimizing response burden and increasing response authenticity. Data collection took place over a defined period, after which responses were exported to a spreadsheet format for analysis. Incomplete or inconsistent responses were screened and excluded from the dataset prior to analysis.

D. Data Analysis

Data analysis was conducted using descriptive statistical techniques. Frequencies, percentages, means, and standard deviations were calculated to summarize respondents' evaluations of AI-related stressors and facilitators. Given the exploratory nature of the study, the emphasis was placed on identifying overall trends rather than testing causal relationships. The results were interpreted in relation to contemporary theoretical frameworks on occupational stress, technostress, and human-centered AI adoption.

E. Ethical Considerations

The study was conducted in accordance with established ethical standards for social research. Participation was anonymous and voluntary, and respondents were informed of their right to withdraw at any time. Data were stored securely and used exclusively for academic purposes. The research was carried out by academic staff and students of *Dimitrie Cantemir University of Târgu Mureș*, contributing to the broader academic investigation of human–technology interaction in the workplace.

Results

This section presents a detailed descriptive analysis of employees' responses regarding the influence of artificial intelligence (AI) on occupational stress. The results are based on **247 respondents** and rely on descriptive statistical indicators, including means (M) and standard deviations (SD). All questionnaire items were measured on a five-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*).

General Attitudes Toward Artificial Intelligence

Respondents demonstrated an overall positive orientation toward artificial intelligence as a workplace technology. The perceived usefulness of AI achieved a relatively high mean score ($M = 3.88$, $SD = 0.81$), suggesting that most employees recognize the practical value of AI systems in supporting their professional activities. This finding indicates that AI is largely viewed as a functional and relevant component of modern work processes rather than an abstract or distant technology.

Similarly, the belief that AI contributes to increased efficiency and productivity was strongly endorsed ($M = 3.72$, $SD = 0.84$). Many respondents perceived AI as a tool that accelerates task completion, optimizes workflows, and reduces unnecessary effort. However, self-reported understanding of how AI systems operate was only moderate ($M = 3.41$, $SD = 0.90$). This gap between perceived usefulness and depth of understanding suggests that employees may rely on AI pragmatically without fully comprehending the underlying mechanisms, which has implications for trust and long-term adaptation.

AI-Related Stress and Emotional Responses

Direct indicators of AI-related occupational stress revealed relatively low levels of perceived strain. The statement “The use of AI at work increases my level of stress” produced a low mean score ($M = 2.19$, $SD = 0.97$), indicating that most respondents disagreed or leaned toward disagreement. Similarly, feelings of anxiety or uncertainty when working with AI systems were reported at low to moderate levels ($M = 2.23$, $SD = 1.01$).

These results suggest that, at the time of data collection, AI is not perceived as an immediate or dominant stressor in the workplace. Nevertheless, the relatively large standard deviations indicate variability in individual experiences, implying that while many employees feel comfortable with AI, a notable minority experiences discomfort or emotional strain. This heterogeneity highlights the importance of considering individual differences when assessing the psychological impact of AI adoption.

Job Insecurity and Future-Oriented Concerns

Concerns related to job insecurity represent a central theme in discussions about AI and work. In this study, respondents expressed moderate agreement with statements suggesting that AI could replace some of their current tasks ($M = 2.52$, $SD = 1.06$). A similar pattern was observed for concerns that AI might reduce the need for human employees in the future ($M = 2.56$, $SD = 1.08$).

Although these mean values remain below the scale midpoint, they reflect a latent awareness of AI’s potential long-term implications. Employees appear to acknowledge the possibility of task automation without perceiving it as an immediate threat. This cautious stance suggests that job insecurity related to AI is present in a diffuse and anticipatory form rather than as acute stress. However, such concerns may intensify as AI technologies become more advanced and more deeply integrated into core organizational functions.

Perceived Control, Transparency and Trust

Perceptions of control and transparency play a crucial role in shaping employees’ psychological responses to AI. In the present study, respondents generally disagreed with the notion that AI causes a loss of control over work processes ($M = 2.34$, $SD = 0.95$). This finding indicates that most employees still perceive themselves as active agents in their work, rather than passive executors of algorithmic decisions.

At the same time, concerns regarding the transparency of AI-driven decisions were moderately expressed ($M = 2.47$, $SD = 0.99$). This result suggests that while employees do not feel overtly disempowered, they remain uncertain about how AI systems reach certain conclusions or recommendations. Trust in AI-generated outputs reflected this ambivalence, with a near-neutral mean score ($M = 2.96$, $SD = 0.88$). Respondents neither strongly trusted nor distrusted AI recommendations, indicating a cautious and evaluative attitude.

Together, these findings point to a conditional acceptance of AI: employees are willing to use AI tools, but their trust is contingent on perceived reliability, explainability, and alignment with human judgment.

Impact on Workload and Task Structure

One of the most frequently cited benefits of AI in the workplace is its potential to reduce repetitive or monotonous tasks. In this study, respondents moderately agreed that AI had reduced repetitive workload ($M = 3.18$, $SD = 0.92$). Furthermore, AI was perceived as enabling employees to focus more on complex or creative tasks ($M = 3.29$, $SD = 0.89$).

These findings suggest that AI contributes to qualitative changes in work rather than simply increasing or decreasing workload volume. By shifting task composition, AI may enhance job enrichment for some employees. However, the moderate strength of agreement indicates that this benefit is not uniformly experienced and may depend on the specific nature of job roles and AI applications.

Adaptation to AI-Driven Changes

Employees generally reported a satisfactory level of adaptation to AI-related changes in their work environment ($M = 3.44$, $SD = 0.86$). This result implies that most respondents perceive themselves as capable of adjusting to technological innovations, even in the absence of complete mastery. Adaptation appears to be driven more by experiential learning and practical exposure than by formal training.

Nevertheless, adaptation should not be interpreted as the absence of strain. Rather, it reflects a dynamic process in which employees continuously recalibrate their skills and expectations in response to evolving technologies.

Organizational Support and Training

Organizational factors emerged as one of the weakest areas in the results. Respondents expressed low agreement with statements indicating that their organizations provide sufficient AI-related training ($M = 2.41$, $SD = 1.02$). This suggests that many employees feel inadequately prepared to use AI tools to their full potential.

Perceived access to help or support when encountering difficulties with AI was only moderate ($M = 2.98$, $SD = 0.94$). While some support structures may exist, they appear insufficiently formalized or consistently accessible. This lack of institutional support represents a potential risk factor for future stress, particularly as AI systems become more complex and pervasive.

Integrated Interpretation of Findings

Taken together, the results portray a nuanced picture of AI's role in occupational stress. AI is largely perceived as useful, efficient-enhancing, and manageable in the present context. Direct stress and anxiety levels associated with AI remain relatively low, indicating a generally

favorable climate of acceptance. However, moderate concerns related to job insecurity, transparency, trust, and insufficient organizational support highlight underlying vulnerabilities.

These findings suggest that occupational stress related to AI is currently latent rather than acute. Without proactive organizational strategies focused on training, communication, and ethical governance, these latent concerns may evolve into more pronounced stress responses as AI adoption deepens.

Conclusion

The present study set out to explore the influence of artificial intelligence on occupational stress from the perspective of employees, with a particular focus on perceptions, concerns, and adaptive responses in contemporary work environments. The findings provide a balanced and empirically grounded picture, moving beyond polarized views that portray AI either as a major threat to employee well-being or as an unequivocal solution to work-related stress.

Overall, the results indicate that artificial intelligence is predominantly perceived as a useful and efficient-enhancing tool. Most employees do not currently experience AI as a direct source of occupational stress or anxiety. On the contrary, AI is often associated with reduced repetitive workload and with opportunities to engage in more complex or meaningful tasks. These findings suggest that, at this stage of adoption, AI functions more as a supportive resource than as a stressor, contributing positively to everyday work experiences.

At the same time, the study highlights several latent risk factors that may shape future stress trajectories. Moderate concerns related to job insecurity, algorithmic transparency, and trust in AI-generated outputs point to an underlying ambivalence in employees' attitudes. While these concerns do not translate into high stress levels at present, they represent potential sources of strain that may intensify as AI systems become more autonomous and deeply embedded in organizational decision-making processes.

A particularly important conclusion emerges with regard to organizational support. The low levels of perceived training and only moderate access to assistance when encountering difficulties with AI suggest that many organizations are insufficiently prepared to support employees through technological transitions. This gap constitutes a critical vulnerability, as inadequate training and support are well-established predictors of technostress. Without proactive interventions, the current phase of cautious acceptance may evolve into frustration, reduce self-efficacy, and increase occupational stress.

From a theoretical perspective, the findings reinforce contemporary views that the impact of artificial intelligence on occupational stress is not determined by technology alone. Rather, it arises from the dynamic interaction between technological demands, individual capabilities, and organizational context. Artificial intelligence is neither inherently stressful nor inherently stress-reducing; its effects depend on how it is designed, implemented, and governed.

In practical terms, the study underscores the need for human-centered AI strategies that prioritize transparency, continuous training, ethical governance, and employee involvement. By addressing these dimensions, organizations can mitigate potential stressors and foster a sustainable integration of AI that supports both performance and employee well-being.

In conclusion, artificial intelligence represents a transformative force in the world of work, carrying both promise and risk. Understanding employees' lived experiences is essential for ensuring that this transformation enhances, rather than undermines, occupational health and long-term organizational resilience.

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EMOTIONAL INCLUSION: THE ROLE OF AI AND VR IN SUPPORTING VULNERABLE STUDENTS.

Professor Aurel PAPARI Ph.D., Professor Adrian PAPARI Ph.D., Assist. Prof. Irina ȘUNDA Ph.D.

*“Andrei Șaguna” University, Constanța, Romania
Corresponding author: Irina Șunda: rinasunda@andreisaguna.ro*

Abstract

The article analyzes innovative ways of teaching literary genres in primary grades, emphasizing the integration of emerging technologies such as artificial intelligence and augmented reality. It highlights the benefits of combining traditional methods, such as dramatization lessons, with interactive digital tools, which stimulate students' creativity, affective involvement and critical thinking. The proposed didactic examples include role-playing games, multimedia fables and collaborative workshops assisted by AI, facilitating the adaptation of content to the level of each child and providing personalized feedback. The article emphasizes the importance of maintaining a balance between innovation and tradition for the development of communication skills and literary education. The conclusion suggests that emerging technologies are transforming the teaching of literature, preparing students for the demands of modern education.

Keywords: VR depression IA

Introduction

In today's rapidly changing educational landscape, emotional well-being has become an essential component of true inclusion. Many students face invisible challenges - particularly depression - that can quietly undermine their academic performance and sense of belonging. As these struggles often go unnoticed, universities need new ways to understand and support vulnerable learners.

Artificial Intelligence (AI) and Virtual Reality (VR) offer powerful tools to bridge this gap. AI can personalize learning experiences and identify early signs of academic decline without diagnosing or labeling students. VR can create immersive environments that foster empathy, reduce stress, and provide safe spaces for emotional reflection.

“The Noonday Demon”

Depression is considered the disease of the present century, both because of the disability it generates and the incidence in the population, which according to WHO analyzes and statistics, has increased in recent years by 18%, affecting about 350 million people, being considered the first cause of disability worldwide, before TB and car accidents.

Recent studies show that depression is occurring at an increasingly young age, both in women and men and in all economic and social settings, so the poles of depression are changing.

Starting from the increasingly young age of people affected by depression and the complexity of symptoms in adolescents and researching the field, which is riddled with studies that signal the presence of depressive symptoms in students, we chose as subjects this age category.

Suicidal ideation is common in adolescents, both in Romania and globally, representing a major problem, both in terms of severity and the fact that it can lead to death.

Depression is more common among adolescents than is statistically reported, as it is often unrecognized or even hidden due to the public stigma surrounding mental disorders.

Today's students may face a number of mental health issues that affect their behaviour and decrease their performance. More and more students with diagnosed mental illness (depression, bipolar disorder, anxiety disorder, personality disorder and Asperger's disorder) are admitted to college. In addition, teens seem to have less developed coping skills to use when they are stressed and disappointed.

On the other hand, universities are increasingly aware of the need to pay special attention to students, and from a psychological point of view, not just pedagogically, taking into account the difficulties of accommodation of some of them, or even the inability to do the effort required by academic requirements, as well as the risk of developing depressive symptoms that could jeopardize the success of studies or even their completion.

According to a study that examined the association between self-reporting of depressive symptoms and student academic performance, a significant negative relationship was identified between them. Moreover, it is found that students with a moderate level of intensity of depressive symptoms had lower school performance compared to those with minimal levels of depression. The results reveal the need for screening measures as well as appropriate interventions to reduce moderate depressive symptoms, which have a major impact on academic performance.

Students with such disorders are at risk of poor academic performance and developing resistance to anything related to school, manifested by lack of classroom involvement, poor relationships with colleagues and teachers as well as disinterest in pursuing passions and planning for the future. Learning is affected by the fact that depression negatively affects working memory, making it difficult to store new information and remember previously learned information.

When students are depressed or anxious, they are more likely to try to disconnect from classes when meeting their classmates, as well as to avoid certain situations, such as taking exams.

Depression is becoming more common among students, citing mental health issues as the biggest barriers they face in their learning effort (16% of students reported that depression had a negative impact on their academic performance in 2017).

At “Andrei Şaguna” University, in 2021, The Beck depression inventory was applied to the study group of 450 students in two different stages, before the start of the winter session and after its completion, in the first week of the beginning of the second semester.

After quoting the questionnaires, it turned out that 29.3% of students have a certain degree of depression, 11.3% mild depression, 9.6% moderate depression and 8.4% severe depression.

VR and Emotions

Virtual Reality has the power to transform how we understand emotional and psychological struggles - such as depression - because it creates immersive, first-person experiences that go

beyond abstract descriptions. Instead of simply hearing about how a vulnerable student feels, VR allows educators, peers, and even the students themselves to step into a simulated environment that reflects common challenges associated with low mood, lack of focus, social withdrawal, or overwhelming academic pressure.

VR can show potential to facilitate the treatment process and motivate patients with depression in various ways, which may improve treatment outcomes, as most studies demonstrated the use of VR to be effective for supporting the treatment of anxiety or depression.

Through controlled and realistic scenarios, VR can reproduce cognitive and emotional barriers (difficulty concentrating, slowed thinking, or sensory overload), can simulate social situations where a student may feel isolated or disconnected. It can also show the impact of negative self-talk or rising academic stress in a safe and guided way.

VR can help educators develop empathy by experiencing, even briefly, what a student with emotional vulnerability might face and it can offer calming, structured spaces that support reflection and stress reduction.

This immersive perspective can deepen emotional understanding, reduce stigma, and encourage more compassionate responses - something that traditional explanations or lectures often fail to achieve.

The Treatment of Depression Using VR

Using electronic devices such as a head-mounted display (HMD), individuals can immerse themselves in computer-generated simulation of real-world environments, allowing them to explore and interact with these virtual settings.

Virtual reality is becoming a powerful tool in educator training, offering immersive experiences that build empathy and sharpen observational skills. By placing teachers inside the emotional and cognitive world of students who struggle with depression, VR simulations can deepen understanding and improve classroom responses.

VR can support educators in recognizing and addressing student needs. Teachers step into the morning routine of a student experiencing depression. The simulation portrays the heavy emotional weight that can make even simple tasks feel over-whelming getting out of bed, choosing clothes, or preparing for school. Motivation is noticeably low, and decisions that would normally be effortless require significant mental energy. By navigating this slowed, burdened version of everyday life, teachers gain a deeper appreciation for the invisible challenges many students face before they even arrive at school. The goal is to cultivate empathy and awareness of internal struggles that are often hidden behind a calm or neutral exterior.

Teachers can enter a virtual classroom from the perspective of a student dealing with depressive symptoms. Ordinary sounds become uncomfortably loud, concentration fades quickly, and social interactions feel intimidating or draining. The simulation replicates the sense of being disconnected or overwhelmed, helping teachers understand why students may withdraw, avoid participation, or seem disengaged. By experiencing these barriers firsthand, educators can better adapt their communication strategies and create classroom environments that feel safer and more supportive.

Teachers should focus on observation and early detection. They interact with a virtual student whose behaviour changes gradually: missed assignments, reduced participation, quieter demeanour, or shifts in body language. Throughout the simulation, prompts guide teachers in

identifying these early indicators of emotional or academic decline. This reinforces the importance of noticing small but persistent changes, initiating supportive conversations, and connecting students with appropriate resources. It helps educators build confidence in recognizing when a student might be struggling, even if the signs are not immediately obvious.

Together, these VR scenarios offer educators a meaningful way to understand and respond to students facing depression. By making the invisible visible, they empower teachers to create more compassionate, informed, and responsive learning environments.

Virtual reality is emerging as a valuable tool for helping students manage stress, build emotional skills, and strengthen academic confidence. By offering immersive, controlled environments, VR experiences can guide students through challenges that may otherwise feel overwhelming. VR can be used to promote emotional and cognitive well-being in educational settings.

Students are placed in calming, immersive settings — such as forests, beaches, or quiet study rooms — where they engage in guided breathing or mindfulness exercises. The goal is to help students regulate anxiety, regain emotional balance, and refocus their attention. Also, students practice navigating simulated test environments while learning techniques such as grounding strategies, positive self-talk, and effective pacing. This combination reduces exam-related stress and strengthens overall academic resilience.

In some interactive exercises, students break complex tasks into smaller, manageable steps and visualize their priorities within a serene VR space. The purpose is to help those who feel overwhelmed by assignments or deadlines develop clearer thinking and better planning habits.

VR journals, reflective prompts, and visually supportive environments guide students in identifying, labelling, and exploring their emotions. By offering a nonjudgmental space for reflection, these scenarios promote emotional awareness and literacy.

Gentle simulations introduce collaborative activities or group interactions, helping students ease back into social settings. These experiences are especially beneficial for those dealing with isolation, offering a gradual and supportive path to rebuilding social confidence.

How AI Supports Personalization and Monitoring Without Providing a Diagnosis

Artificial intelligence can play a meaningful role in supporting vulnerable students by personalizing learning and monitoring academic well-being - without crossing into clinical territory. Its function remains strictly educational, helping institutions respond more effectively while preserving student privacy and avoiding diagnostic claims.

AI focuses on observable academic behaviours such as attendance, assignment completion, participation in digital platforms, and changes in performance. By monitoring trends rather than psychological indicators, the system highlights when a student may need additional support without making assumptions about their mental health.

When a student repeatedly misses deadlines, disengages from class activities, or displays inconsistent learning patterns, AI can notify advisors or instructors. These alerts do not classify or diagnose; they simply signal that the student might be facing challenges that warrant attention.

AI adapts instructional elements such as lesson difficulty, pacing, content volume, examples, reminders, and study schedules. These adjustments help students manage fluctuating energy levels or concentration difficulties that may stem from emotional or situational stress, enabling them to stay engaged in a way that suits their needs.

By breaking down complex tasks and providing targeted motivational prompts, AI assists students who feel overwhelmed academically. This support helps maintain steady progress without making any inferences about a student's mental health status.

AI-driven chat tools create a confidential space for students to ask questions, express uncertainty, or seek clarification. They can also guide students toward relevant campus support services, doing so in a neutral and nonclinical manner.

AI systems can modify the style, timing, and tone of feedback when academic stress is detected. This may include offering more encouraging messages or suggesting short breaks during intense periods, helping students manage their workload without imposing any psychological interpretation.

Benefits for Inclusion and Stigma Reduction

Integrating AI and VR tools into educational settings can significantly improve inclusion while reducing the stigma often associated with seeking support. When these technologies become part of everyday learning, students experience help as a normal and accessible resource rather than something that sets them apart. Support becomes universal instead of exceptional, easing feelings of shame or difference.

AI platforms also provide private, nonjudgmental spaces where students can ask questions, express concerns, or seek guidance without fear of being evaluated by peers or instructors. This confidential access encourages students who might otherwise remain silent to reach out and engage more openly.

VR simulations further contribute to a more inclusive environment by helping educators and peers understand the internal experiences of vulnerable students. These immersive experiences deepen empathy, challenge harmful assumptions, and promote more compassionate interactions across the classroom.

Through adaptive pacing, task adjustments, and tailored explanations, AI creates learning environments that feel achievable for every student, regardless of emotional or cognitive challenges. This personalized support helps prevent feelings of being “behind,” excluded, or inadequate.

AI's ability to quietly monitor academic patterns means students can receive help early, before difficulties become visible or escalate. This discreet form of assistance protects student dignity and reduces the social pressure associated with asking for help.

As institutions adopt these tools, they reinforce the idea that emotional well-being is an essential part of learning rather than a sign of weakness. This shift helps transform the culture from one of stigma to one of understanding and solidarity.

By combining personalized guidance, stress-reducing experiences, and supportive virtual environments, students feel more confident returning to classes, participating, and reconnecting with peers. Ultimately, these technologies empower students to re-engage fully, strengthening inclusion and reducing the risk of isolation.

Conclusion

Artificial Intelligence (AI) and Virtual Reality (VR) can promote emotional inclusion and support vulnerable students, particularly those facing depression. As universities confront rising levels of emotional distress among students, digital tools offer new ways to understand and respond to these challenges without crossing into clinical diagnosis.

AI contributes by personalizing learning pathways, monitoring academic engagement, and offering discreet, nonjudgmental support based solely on educational data. Through adaptive pacing, tailored feedback, early alerts on declining performance, and private study assistance, AI helps students maintain academic continuity even during periods of emotional difficulty. At the same time, it ensures that monitoring remains ethical, focusing strictly on learning behaviours and not mental health assessment.

VR complements this process by creating immersive environments that enhance empathy and emotional awareness. For educators, VR simulations provide first-person insights into the daily experiences of students struggling with depression—difficulty concentrating, social withdrawal, or overwhelming stress. For students, VR offers guided relaxation spaces, confidence-building exercises, and structured tools for managing cognitive overload. These environments allow emotional expression and self-regulation in a safe, controlled setting.

Together, AI and VR reduce stigma by normalizing access to support, fostering greater empathy within campus communities, and ensuring that help is available privately and without judgment. By integrating these technologies into everyday academic life, institutions can create learning environments that recognize emotional well-being as an essential dimension of inclusion.

This article highlights AI-driven personalization strategies, demonstrating how technology can strengthen student resilience and transform higher education into a more compassionate, responsive, and inclusive space.

In a world where many students carry invisible emotional burdens, AI and VR offer us more than technological progress — they offer us the chance to build learning environments rooted in understanding, compassion, and true inclusion. These tools do not replace human connection; they amplify it. They help us see what is often unseen, support those who struggle silently, and create pathways where vulnerability is met with care rather than stigma.

AI-driven adaptive systems can dynamically tailor learning experiences to individual needs, enhancing personalised instruction and engagement, while VR provides immersive, multi-sensory environments that facilitate experiential learning and social interaction. Together, these technologies offer promising avenues for creating inclusive educational settings that support emotional regulation, accessibility, and meaningful participation in learning activities. However, significant challenges remain, including high implementation costs, technical barriers, and limited educator preparedness, as well as concerns related to data privacy and algorithmic bias. The evidence underscores the necessity for further empirical research and the development of supportive institutional frameworks to ensure equitable access and responsible integration of AI and VR tools in educational contexts, with the overarching goal of enabling all students — including those most vulnerable — to achieve positive educational and emotional outcomes.

VR has the potential to personalize and enhance interventions for depression; however, further research is needed to clarify the underlying mechanisms of change and to demonstrate the actual effectiveness of this technology.

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PREDICTIVE PATTERNS OF CLINICAL DISORDERS IN ADOLESCENCE

Lecturer PhD Traian MOLDOVAN¹, Lecturer PhD Sorina MOLDOVAN²

¹University of Arts of Târgu Mureș, Career Counselling and Guidance Center

²“Dimitrie Cantemir” University of Târgu Mureș

Corresponding author: Traian Moldovan: traianmol@yahoo.com

Abstract

Mental health problems in adolescents are more common than initially believed, but fortunately, most are manageable and treatable. The fast-paced dynamics of daily life, significant social pressure regarding academic performance, frequent exposure to aggressive and violent content, the risk of poverty represent significant vulnerabilities for the development of clinical disorders during adolescence. Research attempts to identify the relevance of predictors related to personality structure and clinical disorders in explaining psychosocial problems during adolescence. Constructing predictive models with such content can be an important argument for improving diagnostic, prognostic, and therapeutic components of addressing clinical disorders in adolescence.

Keywords: Adolescence, Clinical disorders, Psychosocial problems, Predictive models

1. Introduction

Research activity and epidemiological studies conducted in the past decade in the USA, Canada, and other countries reflect the fact that a significant percentage of adolescents develop a major clinical disorder in one form or another [1][5]. In many cases, these disorders go untreated unless identified by mental health specialists. Assessing the presence and severity of psychopathology in young individuals is, therefore, a clinically significant activity. Mass media consistently presents dramatic evidence of severe psychopathology or tendencies towards violence exhibited by adolescents. These behaviors often represent the tragic manifestation of psychopathology in adolescents. Even adolescents with mild clinical disorders or subclinical symptoms can experience significant problems related to adaptability and daily functioning.

Addressing the mental health conditions of adolescents has an impact on their future lives, harming both physical and mental health and limiting opportunities for fulfilling adult lives. Recognizing signs of mental health issues and taking appropriate measures for those affected can bring lasting positive changes. Regardless of the specific mental health disorder, early identification and intervention can make treatment more effective.

In a veritable meta-analytic study from the specialized literature regarding clinical disorders in adolescence, the relevance of some predictors for certain clinical disorders is highlighted [6].

The impact of negative life events on mental disorders is an important predictor of multiple psychopathologies [7], including depression [8]- [13], suicidal behavior [14], [15], and anxiety [16]. Stressful life events predict aggression, hyperactivity, conduct problems, and delinquency, regardless of age, in both adolescents [17]- [19] and adults [20].

2. Objective and Hypothesis

The aim of this research is to identify the main predictors of psychosocial problems in adolescence, considering personality structure and specific clinical disorders. Therefore, predictive models will be constructed for academic problems, self-concept, and interpersonal problems by including predictors related to personality (Extraversion (E), Agreeableness (A), Conscientiousness (C), Emotional Stability (S), and Autonomy (D), as well as clinical disorders that may arise during this age (Conduct Disorder (CD), Oppositional Defiant Disorder (OPD), Major Depression (DEP), Generalized Anxiety Disorder (GAD), Posttraumatic Stress Disorder (PTS), and Substance Abuse (SUB)).

Personality structure and certain clinical disorders in adolescence represent predictive factors of academic problems, self-concept and interpersonal problems.

3. Participants

The research was conducted on a sample of 30 adolescents, aged between 18 and 19 years old, both male and female, during the period 2021-2022.

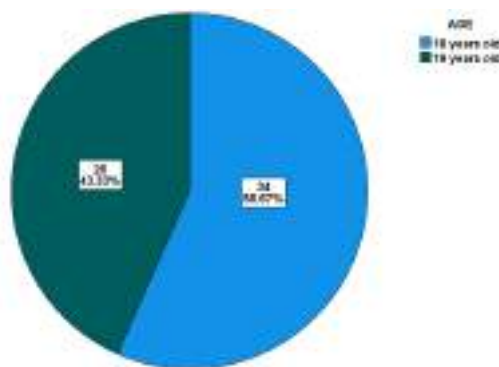


Fig. 1. Distribution of research participants by age

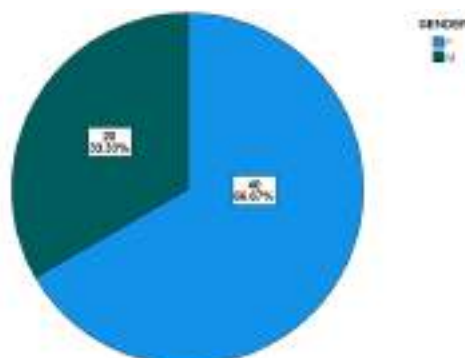


Fig. 2. Distribution of research participants by gender

4. Instruments

The following instruments were used:

1. Five-Factor Personality Inventory (FFPI): The FFPI evaluates the five super-factors of the Big Five model: Extraversion (E), Agreeableness (A), Conscientiousness (C), Emotional Stability (S), and Autonomy (D).
2. Adolescent Problem Scale - Short Form (APS SF): The APS SF consists of 12 clinical subscales and 2 validity subscales. Six clinical subscales focus on DSM-IV symptomatology: Conduct Disorder (CND), Oppositional Defiant Disorder (OPD), Major Depression (DEP), Generalized Anxiety Disorder (GAD), Post Traumatic Stress-disorder (PTS), and Substance Abuse (SUB). The other six subscales evaluate relevant aspects related to adolescents' psychosocial problems: Eating Disturbance (EAT), Suicide (SUI), Academic Problems (ADP), Anger/Violence Proneness (AVP), Self-concept (SCP), and Interpersonal Problems (IPP). The two validity subscales, Defensiveness (DEF) and Consistency Response (CNR), examine aspects related to response validity.

Results

Automatic Linear Modeling

To verify the formulated hypothesis, a multivariate analysis procedure was used to analyze the criteria (Academic Problems, Self-concept, Interpersonal Problems) based on a set of 11 predictors related to personality (Extraversion (E), Agreeableness (A), Conscientiousness (C), Emotional Stability (S), and Autonomy (D)) and clinical disorders in adolescence (Conduct Disorder (CND), Oppositional Defiant Disorder (OPD), Major Depression (DEP), Generalized Anxiety Disorder (GAD), Post-Traumatic Stress Disorder (PTS), and Substance Abuse (SUB)).

For this type of procedure, accuracy of prediction (R-squared) and the relevance of predictors in the model are important. Several conditions must be met for the accuracy of the study. Variables were measured without errors, the normality condition was met, the relationship between dependent (criterion) and independent (predictor) variables was linear, and the predictor variables were relatively orthogonal. The tolerance index has a value greater than 0.25, and the Variation Inflation Index (VIF) values are less than 10, indicating the absence of multicollinearity.

In terms of the regression procedure used in our research, we considered Automatic Linear Modelling as the optimal method. It has advantages such as automatic variable selection, automatic data processing, and superior graphical presentation of results. "Forward stepwise" selection method was chosen for constructing the model, which involves selectively introducing predictors into the equation based on their relevance to the criterion. At each step, the contribution of each predictor is evaluated, and if significant, the predictor is retained in the model. Non-significant predictors or those evaluating the same component are eliminated from the model. Although many researchers prefer the method of including all possible subsets in the model, rather than forward stepwise selection, we found forward stepwise selection method to be more appropriate for our study as it provides greater accuracy for the model.

The Predictive Model for "Academic Problems"

The predictive model demonstrates good accuracy, with an adjusted R-squared value of 57.5%.

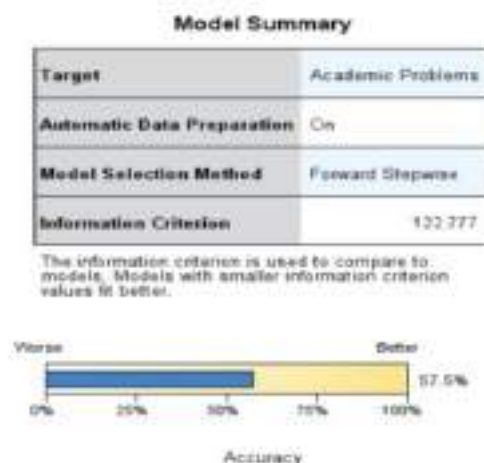


Fig. 3. Summary of the predictive model for Academic Problems

The predictive model demonstrates good accuracy, with an adjusted R-squared value of 57.5%. The predictors explaining this model in order of relevance are: Substance Abuse 35% - positive predictor, Posttraumatic Stress Disorder 33% - positive predictor, and Oppositional Defiant Disorder 32% - positive predictor.

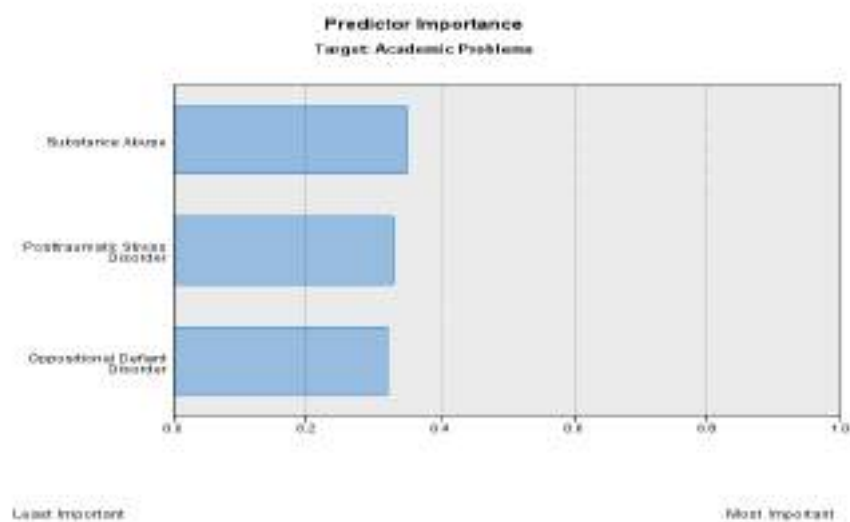


Fig. 4. The list of predictors entered into the "Academic Problems" model.

Clinical profile of Academic Problems (trouble concentrating on a task, very easily distracted, concentration difficulties and conduct problems):

- Chronic substance use, two or more types (alcohol or other drugs). Consumption usually takes place outside of school, the effects are also observed during school activities,

- There are traumatic events in the history, such as a chronic illness, abuse suffered, natural disasters and violence. Remembering the traumatic event can affect school performance and, in some cases, the performance of daily tasks and responsibilities,
- Symptoms that may be present: responses associated with the presence of stress, increased level of agitation, feelings of depersonalization and reliving and remembering the traumatic event,
- Chronic substance use, two or more types (alcohol or other drugs). Consumption usually takes place outside of school, the effects are also observed during school activities,
- There are traumatic events in the history, such as a chronic illness, abuse suffered, natural disasters and violence. Remembering the traumatic event can affect school performance and, in some cases, the performance of daily tasks and responsibilities,
- Symptoms that may be present: responses associated with the presence of stress, increased level of agitation, feelings of depersonalization and reliving and remembering the traumatic event,
- Negativistic, defiant behavior,
- Disobedient and hostile towards the persons who represent the authority (parents, teachers); Main symptoms: lack of obedience, stubbornness, irritability, anger and defiance.

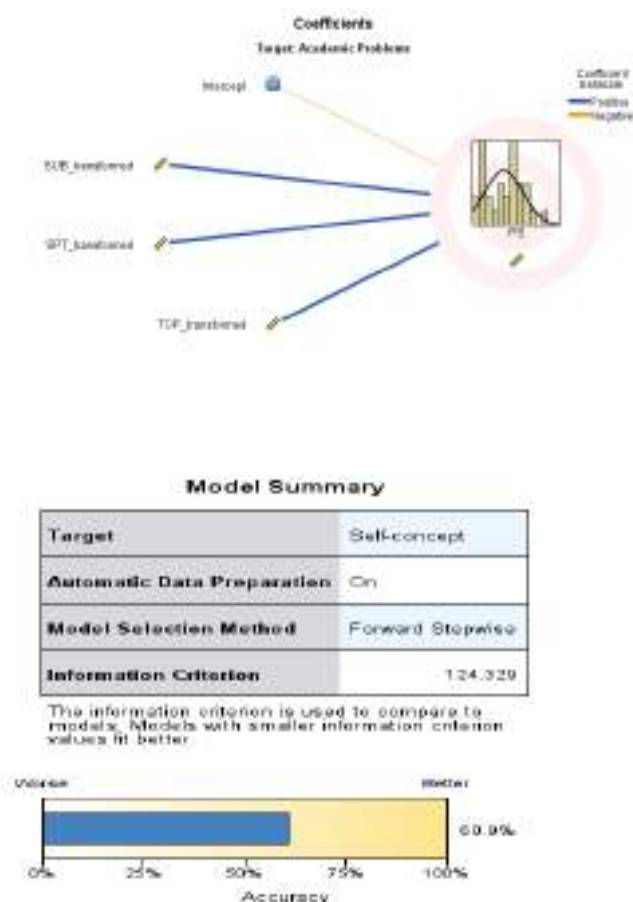


Fig. 6. Summary of the predictive model for Self-Concept.

The predictors that explain this model in order of relevance are: Major Depression 73% - positive predictor, Conduct Disorder 20% - positive predictor and Generalized Anxiety Disorder 7% - negative predictor.

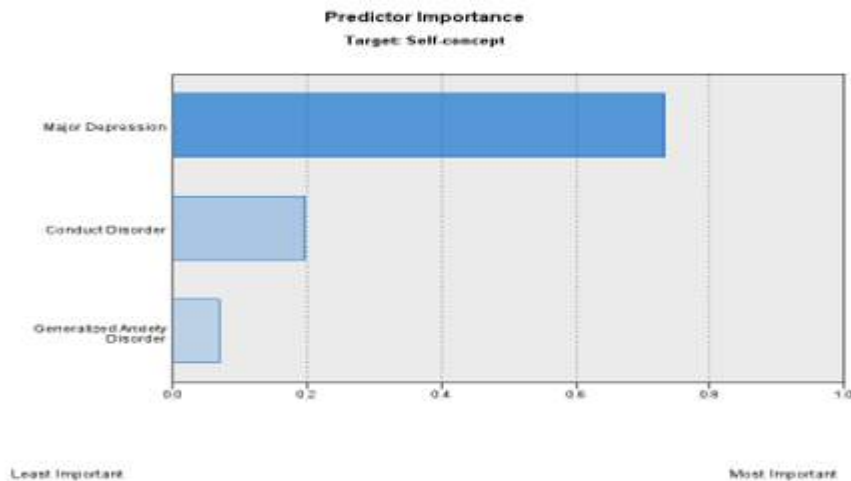


Fig. 7. The list of predictors entered into the Self-concept model

- Clinical profile of self-concept (Self-concept and self-esteem, feelings of worthlessness and self-denigration and self-concept from a physical and social point of view and perception of evaluation by others):
- Dysphoria, distress and sadness. Obvious sadness, withdrawal, disinterest in various activities and withdrawal from friends. Anger towards self and others may be present. Extremely sensitive teenagers with unstable moods;
- Extreme antisocial actions that are significant in their deviation from normal behavior and have a negative impact on others;
- Antisocial behavior, such as stealing, beating, lying, cruelty to animals, using a weapon during a fight, destruction, breaking rules at home and at school, problems with the police or school authorities, or other behavioral problems;
- Physical aggression and destruction of property, lying and stealing and breaking the rules at home and at school;
- Anxiety, worry, fatigue, difficulty concentrating, irritability, physical pain and difficulty falling asleep. nervousness, somatic problems.

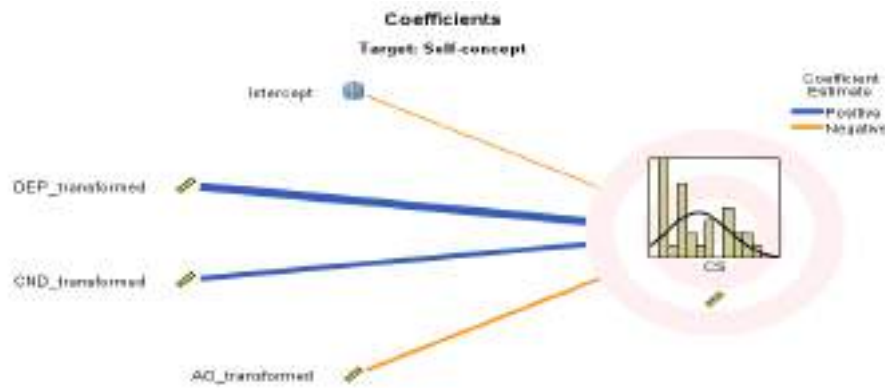


Fig. 8. Ranking of the coefficients in the predictive model "Self-concept".

The Predictive Model for "Interpersonal Problems"

The predictive model for Interpersonal Problems demonstrates good accuracy, with an adjusted R-squared value of 72.1%.

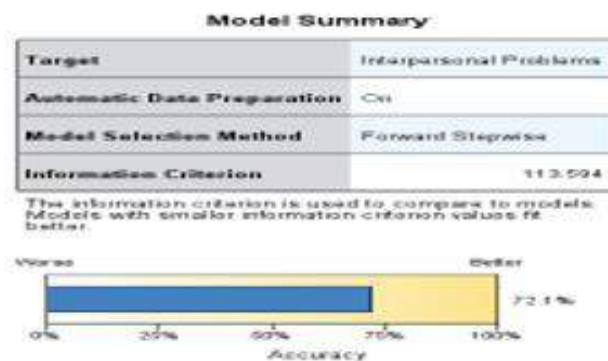


Fig. 9. Summary of the predictive model for Interpersonal Problems.

The predictive model for Interpersonal Problems demonstrates good accuracy, with an adjusted R-squared value of 72.1%. The predictors explaining this model in order of relevance are: Posttraumatic Stress Disorder 50% - positive predictor, Oppositional Defiant Disorder 38% - positive predictor, and Substance Abuse 12% - negative predictor.

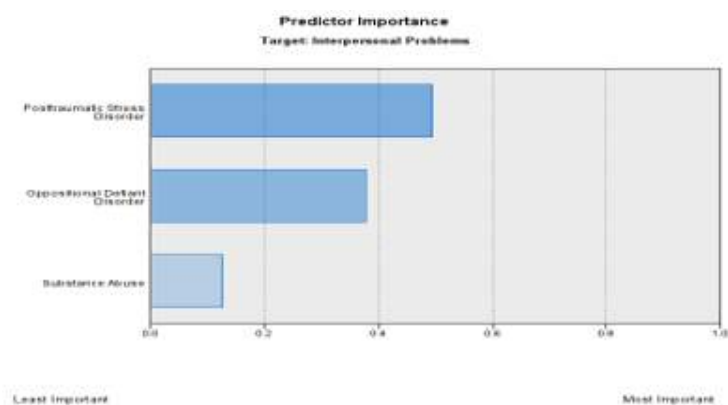


Fig. 10. The list of predictors entered into the Interpersonal Problems model

- Clinical profile of interpersonal problems (Problems related to friendship, loneliness, lack of friends, social withdrawal or social introversion, marked shyness and interpersonal difficulties, including nervousness, loss of temper and difficulty in controlling behavior):
- There are traumatic events in the history, such as a chronic illness, abuse suffered, natural disasters and violence. Remembering the traumatic event can affect school performance and, in some cases, the performance of daily tasks and responsibilities. Symptoms that may be present: responses associated with the presence of stress, increased level of agitation, feelings of depersonalization and reliving and remembering the traumatic event.
- Negativist, defiant, disobedient and hostile behavior towards the persons who represent the authority (parents, teachers). Main symptoms: lack of obedience, stubbornness, irritability, anger and defiance.
- Chronic substance use, two or more types (alcohol or other drugs). Consumption usually takes place outside of school, but the effects are also observed during school activities.

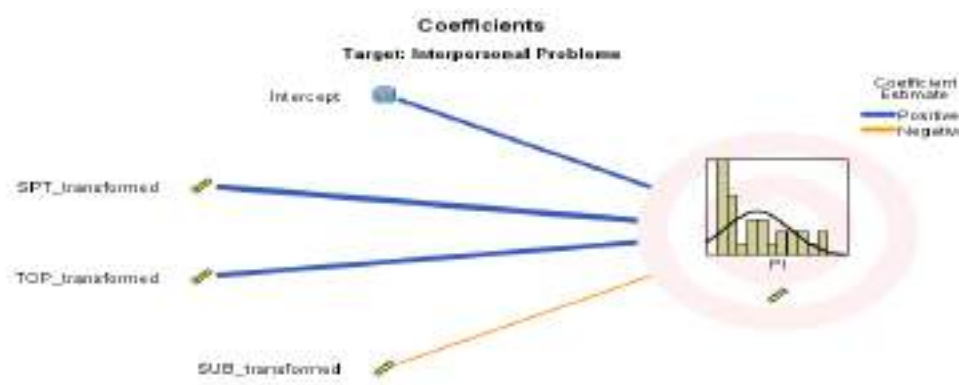


Fig. 11. Ranking the coefficients in the predictive model “Interpersonal problems”

Discussion

Advantages and Limitations of the Research

One of the most important advantages of the research is the proposed research design (non-experimental) for addressing psychosocial issues in adolescence. The model, as a descriptive-predictive scientific approach, attempts to provide theoretical and practical answers regarding the analyzed issues [21]. We believe that through the constructed predictive models, a clearer description of the phenomenon has been achieved, and based on this description, practical solutions have become more obvious. Thus, the pattern of confirmatory research is surpassed, and efforts are focused towards exploratory research, fulfilling one of the objectives of multiple regression analysis, which is the "development of theory testing in psychology - multiple regression is a means by which psychological theories regarding relationships between variables can be tested in reality" [22]. Such predictive models and the creation of explanatory profiles of adolescent problems have superior diagnostic and prognostic utility, enabling the

development of optimally directed intervention strategies. Predictive models, despite their limited potential for causal inference, represent a more faithful replication of reality.

The main disadvantage of the research is the small sample size ($N=30$). In our research, 11 predictors were included in the predictive models, with 5 belonging to personality and 6 to clinical disorders. The number of research participants is determined based on the ratio between the number of participants and the number of independent variables (predictors), which should be 15/1 [22] or by using the formula $N=50 + 8 * m$, where "m" is the number of predictors [22]. Therefore, the minimum sample size for a predictive model with 11 predictors should have been $N=165$, according to the first calculation method, or $N=138$ according to the second. Selecting an optimal number of participants for predictive research is "an important condition for obtaining regression coefficients that are not only significant but also accurate or stable" [22]. However, considering the fact that personality predictors (Five-Factor Personality Inventory) did not enter the model, the assessment of the sample size in our case is relative.

In future research we aim to expand the target group and include other predictors in the model, predictors related to demographic factors, personality traits, and emotional intelligence.

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DOES MAN COORDINATE TECHNOLOGY OR IS HE, ITS SLAVE?

Prof. Lucian Constantin CIOHOTARU

*Religion teacher at the School Center for Inclusive Education, Negrești/Student at Conversion in psychology, The Department of Vocational Training and Postgraduate Studies, „Dimitrie Cantemir” University from Targu Mures, Romania
Correspondent - Ciohodaru Lucian-Constantin: Lucian.ciohodaru@yahoo.com*

Abstract

The paper analyses the relationship between man and technology, debating the fundamental dilemma: does man coordinate technology or become its slave? It presents the effects of automation and artificial intelligence on the labour market, with an emphasis on the disappearance of low-skilled jobs and the necessity of professional retraining. The study highlights technology's impact on spiritual and social life, pointing out the tension between the values promoted by the Church and those propagated by the secular mass media. Through a sociological study conducted on a sample of young people, their value profile in relation to the Church and the online environment is outlined, as well as their capacity to discern between authentic and false information. The main conclusion is that technology, although indispensable for progress, must be integrated into a spiritual and moral framework so as not to become a force of alienation, but an instrument in the service of man.

Keywords: Technology, automation, artificial intelligence, Church, mass media, fake news, spirituality, volunteering, social values, youth

Introduction

An important issue of our time is advanced technology. Nowadays, a large part of physical labor is substituted by advanced technical machines and equipment (computers and robots) which offer an advantage: increased productivity, but also a disadvantage: professional retraining. We ask ourselves: what will the future be like? Will we be replaced by machines and equipment, or will we attempt professional retraining?

In *Rise of the Robots*, an example is provided of a significant decrease in jobs in a US factory in just three decades. Parkdale Mills Textile Factory had “140 employees” in 2013. “In the 1980s, the same level of production would have required more than 2000 workers. Inside the factory, «only occasionally did a person interrupt the automated production line, mainly because manual execution of certain actions is cheaper. » (...) Approximately 12,000,000 jobs – more than three-quarters of the US workforce employed in the textile sector – disappeared between 1990 and 2012, while textile and clothing exports increased by 37%, reaching a total value of \$23 billion.” [1, pp. 36-37].

Nevertheless, the tertiary sector of the economy, the service sector, has developed recently. Regarding this aspect, we learn the following: “In the United States and other advanced economies, the biggest imbalances caused by automation will appear in the service sector, which currently employs the most workers. This trend is already evident (in the case of ATMs

or self-service checkouts, but the next decade will undoubtedly bring an explosion of new and new ways to automate this sector, which has the potential to jeopardize millions of relatively poorly paid jobs.” [1, p. 41].

It is worrying that the unemployment rate will be increasing exponentially; the person without training in the field of advanced technology is left without a job. “As robotics and advanced self-service technologies are implemented in almost every economic sector, they will specifically endanger low-paid jobs that require a low level of education and professional qualification. However, precisely this type of job currently represents the majority of new ones generated by the economy”. [1, p. 59].

It is fascinating that these robots that have taken over a large part of human tasks operate based on narrow artificial intelligence, which represents a small part of human intelligence! This means that the man created by God is irreplaceable and will remain the supreme creature, and the world will be in good order if man is in communion with God and nature.

However, modern man has a weakness: out of the desire for continuous information, he acquires a strong sensitivity when he encounters a worrying piece of news that may not always be true. “People think in stories rather than in facts, figures or equations and, the simpler the story, the better. Every person, group, and nation have their own stories and myths. But throughout the twentieth century, global elites in New York, London, Berlin, and Moscow formulated three major stories that claimed to explain all of the past and predict the future of the entire world: the fascist story, the communist story, and the liberal story”. [2, p. 17].

Nevertheless, we have the feeling that we are at a new beginning caused by the evolution of technology. “The sense of imminent apocalypse and disorientation is exacerbated by the increasingly accelerating pace of technological transformations. The liberal political system was shaped in the industrial age to manage a world of steam engines, oil refineries, and televisions. It is struggling to cope with the current revolutions in information technology and biotechnology. (...) Even more importantly, the two revolutions, information technology and biotechnology, could restructure not only economies and societies, but also our body and mind”. [2, pp. 19-20].

In the past, people only competed with automated machines in physical activities, but currently, they also compete in the field of cognitive skills. “Humans have two types of abilities – physical and cognitive. In the past, machines only competed with them in terms of physical abilities, while humans maintained an enormous advantage over machines – knowledge.” “Thus, as manual jobs in agriculture and industry were automated, new jobs emerged in the service sector that required types of cognitive skills that only humans possessed: learning, analysis, communication and, above all, understanding human emotions.” [2, pp. 32-33].

As technology evolves, humanity faces new problems, and thus the outbreak of a powerful crisis is only a matter of time. “Each of these three problems – nuclear war, ecological collapse, and technological disruption – is sufficient to threaten the future of human civilization. But taken together, they amount to an unprecedented existential crisis, especially as they can ameliorate and aggravate each other”.

In what follows, we will try to synthesize the role of technology, as well as the dangers lurking behind universal communication.

“Social media invite the public to participate, calling for involvement. Through their mode of action, media channels engage exteriority, staging.” [3, 2000, p.90].

The word has great power and is an energy carrier. Through the word, we have the possibility to change the mood of the interlocutor, which is why it is more important to think twice before

speaking. The Holy Fathers say that we have one mouth and two ears, so it is more important to listen than to talk unnecessarily.

“Unlike the Gutenberg galaxy, the communication era massively uses the image. The spectator has the possibility to reconstruct, through a free narrative, the mental projection of the viewed reality.” [3, p. 91].

Nevertheless, “A gap still separates the Churches from the secular media, and this comes from the ideals that animate them: on the one hand, the orientation towards the transcendent and eternity, on the other hand, the concern for materiality and living in the moment.” [4, p. 308].

The Church transmits the Good News, urges us to hope for eternal life, while the secular mass media urges us to enjoy the fleeting things and sometimes neglect the spiritual side of the human being.

“Everyday life in contemporary societies is sustained by myths promoted through mass media. It is found that people need, beyond the Heraclitean changes of the moment, ontological stability. Attentive to demand, communication means adapt their offers and mythologizing and ritualization are methods by which the media game remains competitive”. [4, p. 340].

Man is built of body and soul. If the spiritual-religious dimension is neglected, an attempt is made to replace this side with a profane one. We are increasingly restless. The main cause of inner turmoil is inner dispersal. We want to accomplish several things simultaneously and do not realize that the most important thing is to be at peace with ourselves. Nicephorus the Solitary states the following about our rediscovery: “Therefore, return, or rather, let us return, brothers, to ourselves, completely casting off the counsel of the serpent and the pursuit of things that drag us down. For we cannot achieve peace and familiarity with God until we return, or rather, until we enter into ourselves, as much as we are able.” (Stăniloae, 2016, p. 11) We wonder why when we are not thinking of God, we are haunted by all sorts of thoughts. It is no coincidence that the Holy Apostle Paul urges us: “Rejoice always. Pray without ceasing. Give thanks in everything, for this is the will of God in Christ Jesus for you.” (1 Thessalonians, 5:16-18). It can be seen that God does not ask the impossible of us.

We wonder why our ancestors were happier: life revolved around the Church and prayer. Fasts were kept holy, on Sundays and after the Great Feasts, *Hore* (traditional dances/gatherings) were organized, where young people met, and then married. Theoliptos, Metropolitan of Philadelphia, says the following about our mind: „The mind that flees from outward things and gathers itself inward returns to itself. Then it unites with the word it naturally has in its thought, and through the word it essentially has, it unites with prayer, and through prayer, it ascends to the knowledge of God with all its power and loving sensation”. [5, p.59].

In this world there is a perfect order given by the Creator, but which Man, in his desire to become rich and to become a creator, has repeatedly violated. Saint Gregory Palamas speaks to us about the order of things: “The Great Master, giving such an order to each of the boundaries of the whole, fixed this whole in immobility and simultaneously set it in motion, making it a better-ordered world. And to those found between these boundaries, He distributed, again to each, what is due to it.” [5, p. 398].

Thus, if this order is violated, chaos appears in the world. Nature wants to return to normal. Through man's uncontrolled intervention, vegetation fires erupt, the well-known phenomenon called global warming appears, and various incurable diseases appear in the world. “The violation of spiritual laws (which undoubtedly exist just as physical or chemical ones do) leads to the injury of man's spiritual nature. Many, very many physical illnesses have certain soul diseases as their causes”. [6, p. 223].

Study on the Relationship Between the Church and Mass Media in Contemporary Society

Introduction

The starting point of the present study is the Importance of technology in transmitting the Word of God among today's youth. Having this idea, we subsequently created the working tools within the Social Research Methodology laboratory: a questionnaire and an interview guide, materials that are attached in the annexes of this paper. The research framework was restricted; the questionnaire was addressed to young people who are volunteers or intend to become volunteers within Christian Orthodox youth associations (ATOR, ASCOR), high school students, or university students.

The purpose of the research is: describing the value profile of today's young person regarding the relationship between the Church and mass media, as well as combating the phenomenon of fake news. To achieve the proposed goal, the research is situated on two levels: quantitative and qualitative. Through quantitative research, we aimed at the social values of young people who wished to answer the questions included in the questionnaire, selecting a sample of 141 people aged between 17 and 53, "young people of all ages," as His Beatitude Patriarch Daniel would say.

Hypothesis and objectives of the research

Study context

The study was conducted with the aim of carrying out the practical part of the dissertation paper within the "Dumitru Stăniloae" Faculty of Orthodox Theology – UAIC Iași, Communication and Psychological and Spiritual Counselling Program. Sampling was random; the persons who completed the questionnaire had this instrument made available in several chat groups in which they are volunteers of various NGOs, as well as students and graduates of the Faculty of Orthodox Theology in Iași. The sampling period was July 23 – December 11, 2021.

Hypothesis

The more materials that cannot be verified are disseminated in the online environment, the more young people who are in communion with the Church and frequently access social networks will have the capacity to distinguish an authentic content material from an erroneous one.

Goal

Analysis of the profile of today's young person: closeness to the Church, love for neighbor manifested through involvement in social activities within Christian youth organizations, as well as the capacity to distinguish what is true from what is false in the local mass media.

Objectives

1. To highlight the values of today's young person.
2. Reflecting the importance of religious life today.
3. Reflecting the involvement of young people in the life of the Church.
4. Evaluating the discernment of truth from falsehood in the press.

Research Methodology

Sample design- The sample consisted of 141 people aged between 18 and 53.

Research methods and instruments

The drafted questionnaire aims to measure the degree of young people's involvement in the life of the Church, the age at which they first stepped across the Church threshold, as well as the degree of professing their faith through social media and in the community. Along with the questionnaire itself, we also used the observation method. The type of observation chosen was structured observation, having from the beginning a guide through which data and information are analyzed according to the initial questions.

Analysis methods and techniques

After collecting the data – through observation and completion of the questionnaire, I tried to identify a way to organize, select, transform, abstract, and represent them in a way as relevant as possible for the present research. According to Strauss and Corbin, "coding is the process by which data are disassembled, conceptualized, and reassembled into new data, and it involves minimizing, highlighting, or ignoring some dimensions of them, with the aim of serving the announced intentions of the research." [7, p. 76].

Presentation of Results

The questionnaire was divided into 5 sections: Religiosity and personal life, First moments at Church, The connection between the real world and the virtual world, The relationship between the Church and mass media and Sampling data.

The first section had 4 questions, with the respondent having to express their agreement or disagreement regarding the statement, on a scale from 1 to 5 (1. Not at all, 2. To a small extent, 3. Neither to a small nor to a large extent, 4. To a large extent, 5. To a very large extent).

The second section had two questions, through which the respondent had to provide short answers regarding the first moments spent in Church.

The third section presented the connection between the real and the virtual world, and respondents had to measure the frequency with which they perform certain activities.

The fifth section is the most complex and includes 3 closed questions (one question with multiple choice answers and two questions with a unique answer), as well as two open questions with elaborate answers.

The last section includes the sampling data of the respondents: age, gender, residence environment, occupation, level of completed studies, denomination.

In the present paper, we will detail the following sections: Religiosity and personal life, The connection between the real world and the virtual world, The relationship between the Church and mass media and Sampling data.

Religiosity and personal life

The first item in the questionnaire was "I go to Church on Sundays and on holidays throughout the year." And its purpose was the self-evaluation of the respondent regarding participation in the holy services, as well as the appropriation of moral-religious values.

For this item, 82 respondents stated that they attend services at least once a week, 32 respondents attend once a week, 14 once every two weeks, 9 once a month, and 4 people stated that they attend services once every two months or less often.

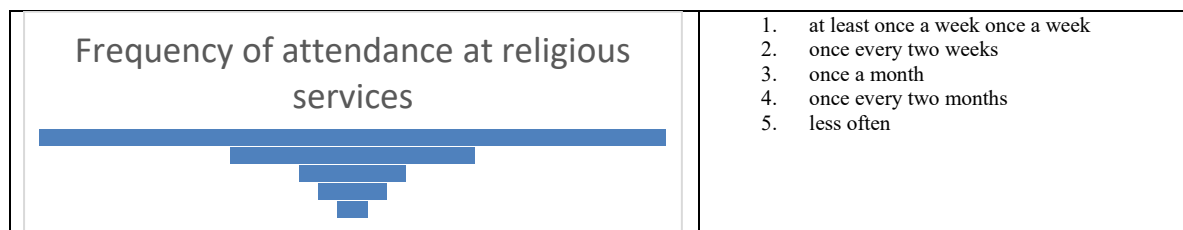


Figure 1. Frequency of attendance at religious services

The second item was "I actively participate in religious services" and its purpose was to measure the believer's involvement in liturgical life (recitation of prayers, chanting of religious songs, as well as participation in the Church choir stand).

For this item, 59 people answered that they participate actively to a very large extent, 41 people participate actively in services, 16 people participate actively to a small extent, 12 people participate actively to a very small extent, and 5 people stated that they do not participate actively in services.

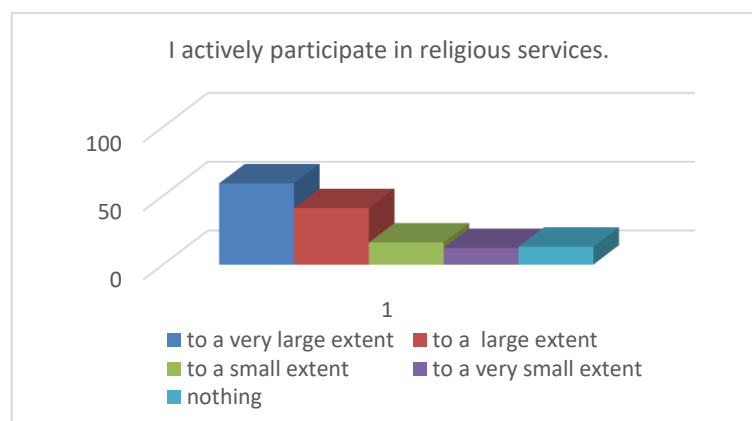


Figure 2. I actively participate in religious services

The third item was "I read at least one chapter from the Holy Scripture and from the books of the Holy Fathers every day" and its purpose was to measure the frequency of daily reading of at least one chapter from the Holy Scripture and from spiritual books.

For this item, 53 people stated that they do not read daily, 33 people stated that they read at least one chapter to a very small extent, 27 people read to a small extent, 20 people read to a large extent, while only 8 people stated that they read daily to a very large extent at least one chapter from the holy writings.

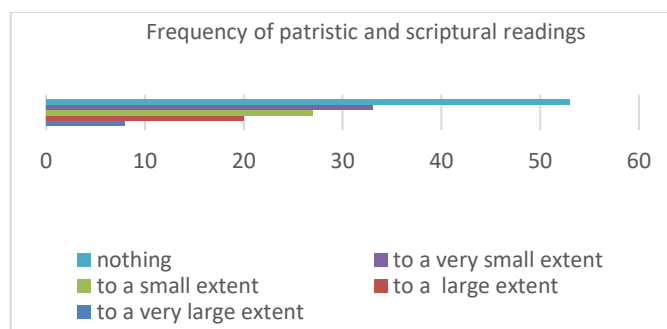


Figure 3. Frequency of patristic and scriptural readings

The connection between the real world and the virtual world

The section "The connection between the real world and the virtual world" aims to evaluate how young people spend time on social networks, as well as the assumption of religious posts on personal social media profiles. This question measures the frequency with which certain actions are carried out: very often, often, sometimes, rarely, very rarely, never.

The following answers were recorded:

Regarding the frequency of accessing social networks: 5 people never access social networks, 9 people access very rarely, 22 people access rarely, 19 people access sometimes, 47 people access often, and 39 people access social networks very often.

Regarding posting materials of a spiritual nature on social networks, 10 people never post, 30 people post very rarely, 29 people post rarely, 39 people post sometimes, 23 people post often, and 10 people post very often.

Regarding watching religious services online: 19 people never watch services online, 34 people watch very rarely, 26 people rarely, 38 people sometimes, 16 people often, and 8 people watch services online very often.

Regarding the sharing of materials of a spiritual nature, 39 respondents share sometimes, 13 share always, while 18 respondents never share materials with spiritual content.

We observe that respondents are active on social networks, sometimes post and share materials of a spiritual nature, and sometimes watch religious services. This demonstrates that religious service is watched online in exceptional situations and that true spiritual experience is found by physically participating in services.

Table 1. Online activity

Action	Never	Very rarely	Rarely	Sometimes	Often	Very often	Total Respondents
Accessing Social Networks	5	9	22	19	47	39	141
Posting Spiritual Messages	10	30	29	39	23	10	141
Watching Services Online	19	34	26	38	16	8	141
Sharing Spiritual Materials	18	24	22	39	25	13	141

We observe that respondents are active on social networks, sometimes post and share materials of a spiritual nature, and sometimes watch religious services. This demonstrates that religious service is watched online in exceptional situations and that true spiritual experience is found by physically participating in services.

The relationship between the Church and mass media

The section "The relationship between the Church and mass media" includes 5 questions, 3 closed questions, and one open question, and aims to evaluate the perception of the relationship between the Church and mass media among respondents.

What are the main sources of information you use?

This first question of the last section aims to count the main means of information for the participants in this study. Thus, 133 people stated that they use the Internet as the main source of information, 57 use TV, 32 people the radio, 26 people the written press, 2 people discussions with friends, 2 people the Church, 3 people books, and 4 people do not inform themselves.

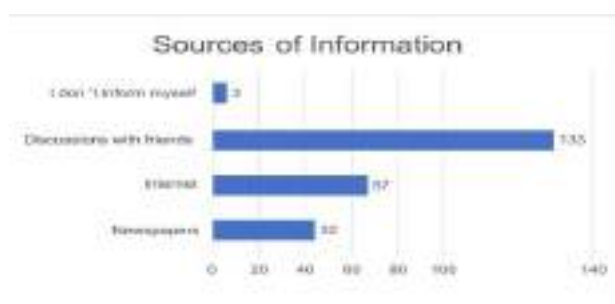


Figure 4. Sources of Information

It can be stated that the vast majority of respondents, given that most respondents are young, are informed primarily from electronic sources. This is where the importance of spiritual discernment comes in, or the gift of distinguishing good from evil, truth from falsehood.

Sampling data

This section aims to present the identification data of the respondents: age, gender, environment of origin, occupation, level of completed studies, denomination. Age- 119 respondents are between 18 and 28 years old, and the others are up to 55 years old.

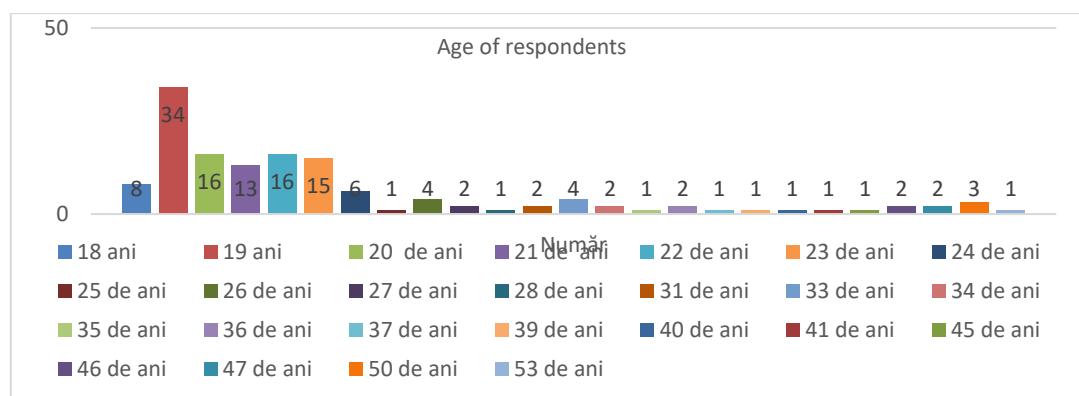


Figure 5. Age of respondents

Gender- 104 respondents are female, 36 respondents are male, and one respondent did not state the gender.

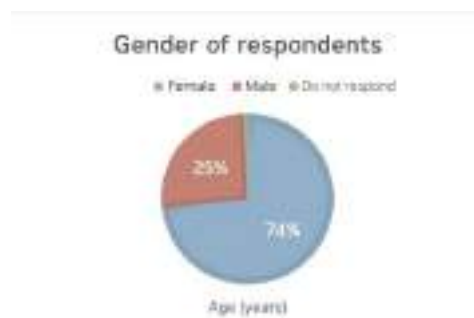


Figure 6. Gender of respondents

Residence environment-In this research, 70 respondents are resident in the rural environment, and 71 respondents are resident in the urban environment.

Conclusions

Nowadays, we are assaulted everywhere by various news, and the consumer society we live in urges us to reflect less on spiritual/eternal things and to concern ourselves with our well-being (comfort, luxury, advanced technology, brand clothing, and food as tasty as possible). The Parable of the Sower comes as a moment of meditation in our lives and makes us stay vigilant, for "we do not know the day nor the hour when the Son of Man comes." I observe the phenomenon of functional illiteracy more and more often people receive the message, but they don't know how to react. I wonder if they are not in one of the three categories mentioned by the Savior. This problem could be solved by guarding the thoughts (freedom from everything that is useless, through prayer and fasting).

This study captures the reality of society reflected on the one hand by the desire for involvement in volunteer activities. Young people are an active force of the Church, going to church from early childhood and getting involved in volunteer activities.

The Church needs a new breath, an adaptation to today's young people, being forced to be visible in the mass media to promote the activities it carries out. Volunteering can be done at any age and whenever the need for passion and involvement is felt.

The first and second parts present the working techniques, as well as the methods and instruments used. The third part presents the research data. Own contributions or what the research brings new. Identifying the desire for involvement among young people.

The extent to which young people put into practice the religious values preached by the Church. Manifestation of interest in involvement in volunteer activities. Assuming the publication and sharing of material with religious content on personal social media pages.

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PART III. DENTAL MEDICINE SECTION

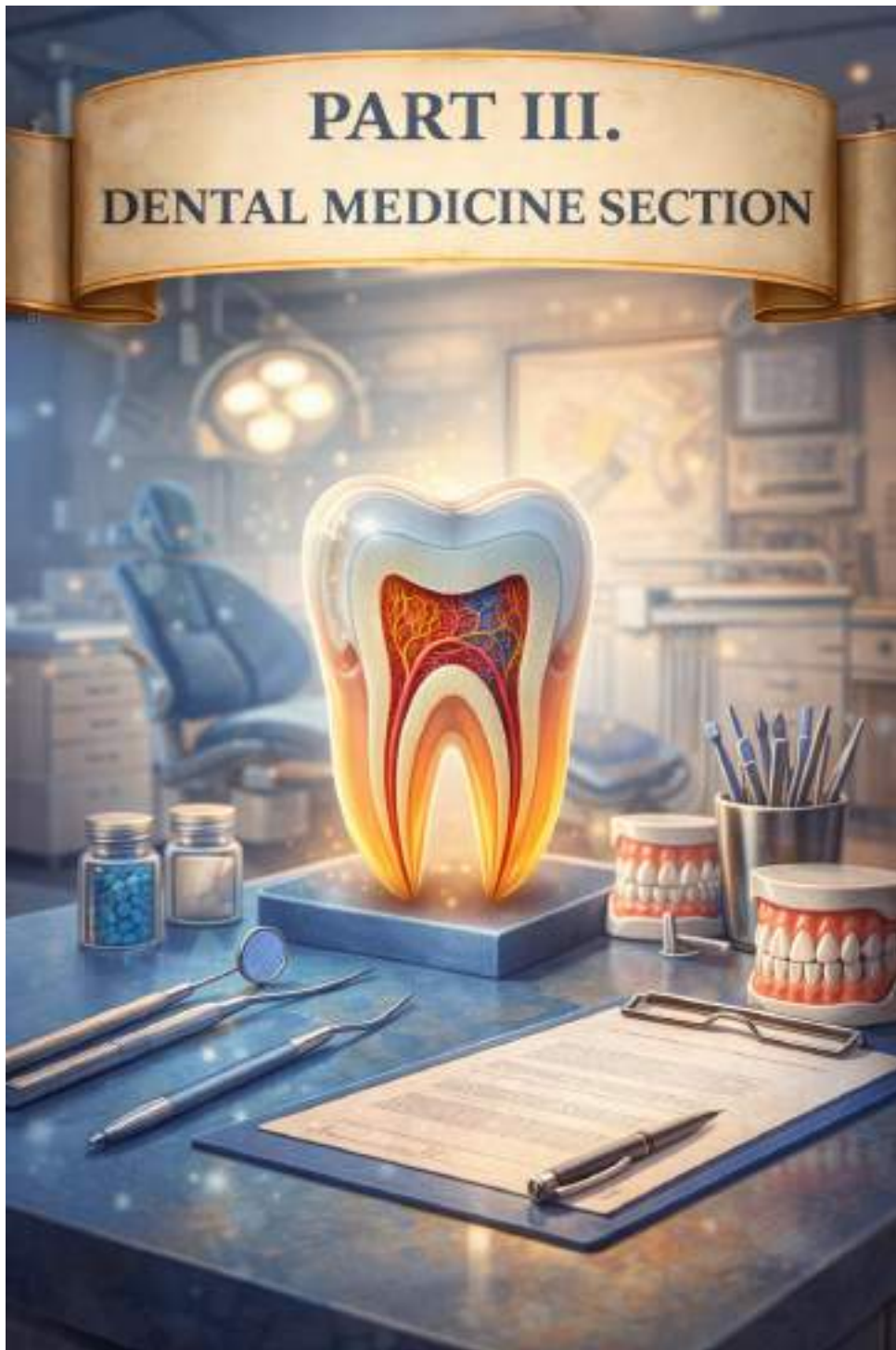


Figure P3. Dental Medicine Section — Clinical Precision and Biomedical Innovation

This illustrative plate was created collaboratively by S.M. Bălan and an AI-assisted design system to reflect the integration of medical science, clinical practice, and technological advancement in dental medicine.

FROM SIMULATION TO SKILL: THE ROLE OF AI AND VR IN HEALTH SCIENCES EDUCATION

**Gabriela KOŁODYŃSKA^{1,2*} Maciej ZALEWSKI³, Aleksandra PIĄTEK³,
Błażej CIEŚLIK¹, Joanna SZCZEPAŃSKA-GIERACHA¹, Waldemar
ANDRZEJEWSKI¹**

¹Wrocław University of Health and Sport Sciences, Department of Physiotherapy, Wrocław, Poland;

²University of Social and Medical Science, Department of Medical Science, Warsaw, Poland;

³Independent Public Health Care Center of the Ministry of the interior and Administration in Wrocław, Department of Gynaecology, Wrocław, Poland

Corresponding author: Gabriela Kołodyńska: g.kolodynska@usmbm.edu.pl

Abstract

The ongoing digital transformation of health sciences education has introduced new possibilities for experiential and competency-based learning. Artificial Intelligence (AI) and Virtual Reality (VR) are no longer experimental tools but integral components of innovative teaching strategies. They enable immersive, adaptive, and data-driven learning environments that allow students to move beyond observation toward active skill development — a process captured by the phrase “from simulation to skill.” Examples drawn from physiotherapy, including applications in urogynaecology rehabilitation supported by biofeedback and sonofeedback, illustrate how immersive learning can enhance clinical readiness, confidence, and precision. These experiences confirm that VR- and AI-based education not only improves technical skills but also fosters reflective practice and professional autonomy. The convergence of AI, VR, and experiential learning marks a significant step toward a more effective, human-centered, and innovation-driven model of healthcare education — one that bridges the gap between simulation and clinical competence.

Keywords: artificial intelligence, virtual reality, simulation, physiotherapy, clinical skills, health sciences education

Introduction

Health sciences education is undergoing a period of rapid transformation, driven by digital technologies that are reshaping the expectations placed on healthcare professionals. Traditional teaching models — centred primarily on lectures, observation, and limited hands-on exposure — are increasingly recognised as insufficient for preparing students for complex clinical environments [1], [2]. Modern healthcare requires practitioners who can integrate large amounts of information, work confidently with digital tools, and apply skills accurately under real-world pressures.

Artificial Intelligence (AI) and Virtual Reality (VR) offer novel learning opportunities that extend far beyond conventional teaching methods. AI supports data-driven instruction, adaptive progression, and automated feedback [3], [4] VR allows learners to experience immersive, interactive scenarios that enhance engagement, reduce performance anxiety, and facilitate the acquisition of complex psychomotor skills [5]- [7]. Together, these technologies contribute to

competency-based learning models that emphasise practice, reflection, and skill consolidation [8], [9].

The idea of progressing “from simulation to skill” reflects this shift. Simulation provides a safe and controlled environment for practice, but the ultimate goal is to translate learning into competent performance in real clinical settings. This article examines how AI and VR support this trajectory by combining immersive experience with structured feedback and reflective learning. Examples from physiotherapy, including VR-supported pelvic floor training [10], [11] illustrate how such approaches enhance confidence, understanding, and clinical readiness.

Research Methodology

The methodological approach used in this article is conceptual and integrative. Three sources form the foundation of the analysis.

1. Literature Review

Key publications regarding VR, AI, simulation-based education, and digital learning in health professions were reviewed to provide context and evidence (Cook & Triola, 2009; [12], [13], [14]) These sources inform the understanding of learning outcomes, technological capabilities, and pedagogical frameworks.

2. Educational Theory

The analysis draws on experiential learning [8], reflective practice [9], and technology-enhanced competency-based education [4]. These theories help explain how learners transition from initial exposure to competent performance.

3. Clinical Example Analysis

Illustrative material from pelvic floor rehabilitation using immersive VR and EMG biofeedback is used to demonstrate how digital environments shape learning. These examples reflect real clinical practice and align with studies on VR-supported rehabilitation [10]; [11].

This combined approach helps us look at AI and VR from both a theoretical and a very practical perspective.

Participants

The clinical examples referred to in this article are based on a previously conducted pelvic floor rehabilitation programme involving postmenopausal women diagnosed with overactive bladder (OAB). Participants were women aged between 50 and 60 years, all of whom met established clinical and safety criteria for inclusion in the training protocol.

Inclusion Criteria

Participants were eligible if they:

- were postmenopausal and over 50 years of age,
- had a diagnosis of OAB,

- presented no contraindications to pelvic floor training or the use of electrostimulation and VR-based interventions,
- did not exhibit acute urinary tract infections or severe neurological disorders,
- were able to participate safely in repeated sessions over a two-week period,
- provided written informed consent for participation in the therapeutic and educational activities.

Exclusion Criteria

Participants were excluded if they:

- presented stress urinary incontinence of grade III or higher,
- had significant neurological conditions affecting bladder control or pelvic floor function,
- were undergoing concurrent therapeutic interventions that could influence study outcomes,
- were pregnant or suspected pregnancy,
- were unable or unwilling to provide informed consent.

Ethical Considerations

All procedures were conducted in accordance with ethical and institutional guidelines, with particular attention to privacy, safety, and the intimate nature of urogynecological rehabilitation. No new data were collected specifically for the purpose of this conceptual educational article. The clinical examples are used solely to illustrate how immersive VR and AI-supported feedback mechanisms can shape learning processes for clinicians and patients in health sciences education.

Material and Method

VR-supported Muscles Training

The VR-based intervention consisted of eight therapeutic sessions delivered over two weeks. The VRTierOne system created an immersive “therapeutic garden” inspired by Ericksonian metaphors, designed to reduce anxiety, promote concentration, and strengthen motivation [11]. Visual, auditory, and kinesthetic elements were linked to the patient’s activity, turning muscles exercises into a structured, symbolically meaningful experience. Such environments are consistent with research showing that VR can increase engagement and emotional readiness for learning in clinical settings [5]; [15]; [16].

Real-time biofeedback was embedded into the virtual scenario, so that correct muscle activation influenced elements of the environment—for example, progressing along a path or “reviving” parts of the garden. This multimodal feedback helped make otherwise invisible neuromuscular processes perceptible, which is particularly important in areas such as pelvic floor rehabilitation where proprioceptive awareness is often limited [10].

Conventional Pelvic Floor Training with EMG Biofeedback

The comparator intervention relied on established electrostimulation protocols combined with EMG visualisation. Participants received biphasic rectangular impulses through intravaginal electrodes, and EMG activity was displayed on a screen. This approach reflects widely accepted standards in pelvic floor training and neuromuscular re-education [17]. While effective, it does not provide the narrative structure and deep immersion offered by VR.

Educational Tools and Outcome Measures

A range of validated questionnaires commonly used in urogynaecology rehabilitation (I-QOL, IIQ-7, PISQ-IR, KHQ, KPS, SES) and ultrasound parameters (POP-Q staging, urethral morphology, bladder wall characteristics, bladder-neck mobility) were used in the underlying clinical work [10]; [11]. In this article, these tools are cited as examples of measurement instruments that could be integrated into AI-supported educational platforms, enabling learners to explore relationships between symptoms, objective findings, and therapy outcomes.

This combination of immersion, feedback, and structured measurement illustrates how digital tools can be embedded in an experiential learning cycle, where each session provides material for reflection, conceptual understanding, and further practice [8].

Results

Qualitative observations from VR-supported and EMG-based pelvic floor training suggest a clear educational advantage of immersive simulation. Participants exposed to the VR environment frequently described the exercises as more understandable, engaging, and emotionally acceptable compared to conventional training alone. These impressions are consistent with broader evidence that VR increases learner engagement, reduces anxiety, and supports the acquisition of complex psychomotor skills in health professions education [1]; [7].

In the VR condition, learners reported that symbolic elements of the therapeutic garden helped them link abstract instructions (e.g., “tighten the pelvic floor”) to concrete, meaningful effects in the virtual world. This type of mediated experience is known to enhance motivation and deepen processing, particularly when combined with repetition and feedback [13]; [14]. For many participants, VR reduced self-consciousness and provided a psychological space in which they felt more comfortable exploring and correcting their technique.

EMG-based training also yielded important benefits. Real-time visualisation of muscle activity supported neuromuscular awareness and contributed to more precise voluntary activation, in line with earlier simulation and skills-training research [2]; [17]. However, without the additional narrative and sensory context of VR, some participants needed more time to integrate what they saw on the screen with what they felt in their body.

Across both interventions, improvements were noted in self-reported confidence, perceived control over symptoms, and readiness to apply learned skills beyond the therapy sessions. Aebersold et al. observed similar reactions were reported informally by nursing students during simulation-based courses at our institution, especially in sessions that involved difficult communication or intimate procedures. [1]; [18].

For teachers, these observations are a strong argument that immersive VR environments and AI-ready feedback systems can help learners move from isolated attempts at performing a task toward stable, transferable competence. This is consistent with models of technology-enhanced

competency-based learning, which emphasise the role of continuous feedback and authentic tasks. [4]; [14].

For instance, some participants spontaneously commented that they “forgot they were in the clinic” and felt more willing to experiment with the exercises in VR than in a standard treatment room. During informal conversations after the sessions, several women said that the VR environment made them “less embarrassed” and “more focused on the task than on the problem itself”, which is rarely reported after conventional training alone.

Conclusion

AI and VR are clearly changing how we teach and learn in health sciences. VR provides realistic, emotionally supportive environments in which learners can practice complex tasks safely and repeatedly. AI enhances these experiences through structured feedback, pattern recognition, and opportunities for personalised learning [3]; [19]. When used together, these technologies support the transition from simulation to genuine clinical competence.

In physiotherapy and urogynecological rehabilitation, immersive tools make subtle physiological processes more accessible and strengthen learners’ confidence. For healthcare education as a whole, AI and VR offer a way to integrate experiential learning, emotional engagement, and reflective practice—elements essential for preparing clinicians who can perform effectively in real-world settings.

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CORRELATION BETWEEN THE DEGREE OF INCISOR PROCLINATION AND THE OCCURRENCE OF GINGIVAL RECESSIONS IN ORTHODONTIC TREATMENTS

Associate Professor Sorana Maria BUCUR Ph.D.¹, University Teaching Assistant, PhD Student Elettra SACCO², Associate Professor, PhD Stefano MARTINA³

¹Department of Dentistry, Faculty of Medicine, Dimitrie Cantemir University of Târgu Mureș, 540545 Târgu Mureș, România;

²Postgraduate School of Orthognathodontics, University of Naples Federico II, Italy;

³Department of Medicine, Surgery and Dentistry "Scuola Medica Salernitana", University of Salerno, Italy.

Corresponding author: Elettra Sacco: Elettra.Sacco@hotmail.it

Abstract

Background: Gingival recession occurs when the gum margin descends toward the tooth root, exposing the underlying surface. This affects dental appearance and may also lead to sensitivity and hygiene issues. The forward tipping of lower front teeth during orthodontic treatment has been considered a potential factor contributing to these recessions. This study aimed to explore whether changes in the inclination of mandibular incisors are associated with the development of labial gingival recessions. **Materials and Methods:** A prospective cohort study was conducted at the Clinic of Dimitrie Cantemir University between June 2022 and June 2024. 86 patients who met the inclusion criteria were evaluated over a one-year follow-up period. Clinical crown height and the presence of gingival recession were measured before treatment, and after one year. Recessions were recorded when the labial cemento-enamel junction (CEJ) was visible. Participants were classified into three inclination groups: less than 94°, between 94°–101°, and greater than 101°. **Results:** The mean participant age was 35.8 ± 8.7 years. Average increases in clinical crown height ranged from 0.62 to 0.81 mm in the non-proclined group and 0.74 to 1.04 mm in the proclined group. These differences were not statistically significant ($p > 0.05$). No meaningful association was found between the degree of incisor inclination and the development of new gingival recessions. **Conclusion:** Proclination of lower incisors after orthodontic treatment did not significantly increase the likelihood of gingival recession in one year. Maintaining proper oral hygiene and careful orthodontic planning remain key to preventing periodontal complications.

Keywords: Gingival recession; Orthodontics; Mandibular incisors; Tooth inclination; Periodontal health.

1. Introduction

Gingival recession is a common periodontal condition defined by the apical displacement of the gum margin, resulting in the exposure of the underlying tooth root surface. This means the protective soft tissue moves further down the tooth, away from the anatomical crown [1]. The landmark separating the tooth crown from the root is the cemento-enamel junction (CEJ), where the enamel meets the cementum. This condition is more frequent in the older population compared to younger individuals [1,2].

The visible exposure of tooth roots due to localized gingival recession often presents significant aesthetic concerns for patients. The resulting appearance of seemingly longer teeth can negatively affect the overall aesthetics and harmony of the smile [1,2].

While the exact cause of gingival recession can be multifaceted, numerous predisposing factors have been clearly identified. These elements either contribute to the initial development or accelerate the progression of the condition [1,3]. A major contributor is chronic inflammation of the gum tissue, stemming from conditions like gingivitis or periodontitis. Physical trauma is also a significant factor, particularly aggressive tooth brushing or the use of hard-bristled toothbrushes, which can lead to the abrasion of both gum tissue and enamel. Other established causative factors include malocclusion, genetic predisposition, tobacco use, and various forms of mechanical trauma [4,5].

Changes in the configuration of the dental arch—the curved alignment of teeth in the jaws—can influence tooth positioning and may lead to conditions such as incisor proclination. Incisor proclination specifically refers to the forward tilt or excessive outward inclination of the incisor teeth [3-6].

The primary objective of the present investigation is to assess the potential association between mandibular incisor proclination and gingival recession. This research aims to provide valuable data for dental clinicians, helping them refine treatment strategies to achieve optimal tooth alignment while preserving long-term gingival health.

2. Materials and Methods

2.1 Study Design and Setting

This investigation was designed as a prospective cohort study to evaluate the development of labial gingival recession in relation to mandibular incisor inclination during orthodontic treatment. The study was conducted at the Clinic of Dimitrie Cantemir University between June 2022 and June 2024, with a dedicated follow-up period of one year. Ethical approval was obtained from the Institutional Review Board, and all participants provided informed consent before enrolment.

2.2 Patient Selection

A total of 86 consecutive patients initiating fixed orthodontic treatment were enrolled in the study based on the following criteria:

Inclusion Criteria

Patients undergoing comprehensive fixed orthodontic treatment.

- Age of 18 years or more at the start of treatment.
- Good general periodontal health (no active periodontitis).
- Presence of all mandibular incisor teeth.
- Availability of diagnostic lateral cephalograms at baseline and after one year.

Exclusion Criteria

- Pre-existing generalized or severe localized gingival recession (Miller Class III or IV).
- History of periodontal surgery in the mandibular anterior region.
- Presence of fixed periodontal retainers or appliances that impede clinical measurements.
- Systemic diseases that affect bone or periodontal tissue metabolism.
- Non-compliance with the one-year follow-up protocol.

2.3 Measurements and Data Collection

All clinical measurements were performed by a single calibrated examiner (ES) to minimize inter-examiner variability.

2.3.1 Clinical Measurements

Clinical assessments were conducted at two time points: Baseline (T0), before the placement of fixed appliances, and One Year Follow-up (T1), after approximately 12 months of active orthodontic treatment. The primary outcome variables were assessed for the four mandibular incisors (teeth 3.1, 3.2, 4.1, 4.2):

1. *Gingival Recession (GR)*: Recorded as present or absent. Recession was defined by the visibility of the labial cemento-enamel junction (CEJ). This landmark was identified by careful probing. If the distance from the free gingival margin to the CEJ was more than 0 mm, gingival recession was considered present.

2. *Clinical Crown Height (CCH)*: Measured with a standardized periodontal probe from the incisal edge of the tooth to the free gingival margin. This measurement was used to quantify any changes in the position of the gingival margin. All measurements were recorded to the nearest 0.1 mm. The change in CCH (ΔCCH) was calculated as:

$$\Delta CCH = CCH_{T1} - CCH_{T0}$$

A positive ΔCCH indicates a movement of the gingival margin apically (recession).

2.3.2 Incisor Inclination Measurement

The degree of mandibular incisor proclination was determined from lateral cephalometric radiographs taken at T0 and T1. The inclination of the most labially inclined mandibular incisor was measured relative to the mandibular plane (Go-Gn) [3, 6, 9]. Based on standard cephalometric norms, participants were categorized into three groups according to their maximum incisor inclination at the one-year follow-up (T1):

Group 1 (Non-Proclined): Inclination $\leq 94^\circ$

Group 2 (Normal Inclination): Inclination $> 94^\circ$ and $\leq 101^\circ$

Group 3 (Proclined): Inclination $> 101^\circ$

2.4 Statistical Analysis

Statistical analysis was performed using SPSS statistical software (version 28.0, IBM, Chicago, IL, USA). Descriptive statistics (mean $\pm$ standard deviation, frequencies, and percentages) were calculated for demographic and clinical variables.

The Independent Samples t-test or ANOVA was used to compare the mean Δ CCH across the three inclination groups.

The Chi-square test was employed to test the association between the categorical variable of incisor proclination group (Group 1, 2, or 3) and the development of new gingival recession.

A significance level of $\alpha = 0.05$ was set for all statistical tests.

3. Results

3.1 Patient Demographics and Baseline Characteristics

A total of 86 patients (mean age 35.8 ± 8.7 years) completed the one-year follow-up. The patient distribution across the three inclination groups, based on their incisor inclination at T1, is summarized in Table 1.

Table 1. Patients distribution across inclination groups

Incisor Inclination Group (at T1)	Inclusion Criterion	Number of Patients (N)	Percentage (%)
Group 1 (Non-Proclined)	$\leq 94^\circ$	24	27.9%
Group 2 (Normal Inclination)	$94^\circ < \text{Inclination} \leq 101^\circ$	38	44.2%
Group 3 (Proclined)	$> 101^\circ$	24	27.9%
Total		86	100%

3.2 Quantitative Changes in Gingival Margin Position

The change in Clinical Crown Height (Δ CCH) for the mandibular incisors was analyzed to quantify the extent of apical migration of the gingival margin (recession). Table 2 presents the average Δ CCH across the three inclination groups.

Table 2. Δ CCH across the three inclination groups

Incisor Inclination Group	Mean Δ CCH (mm) $\pm$ SD	Range of Average Increase (mm)	Statistical Significance (p-value)
Group 1 (Non-Proclined)	0.71 ± 0.35	0.62 to 0.81	$p > 0.05$ (ANOVA)
Group 2 (Normal Inclination)	0.78 ± 0.41	0.70 to 0.86	
Group 3 (Proclined)	0.89 ± 0.44	0.74 to 1.04	

The analysis of variance (ANOVA) comparing the mean Δ CCH across the three groups yielded a p-value greater than 0.05. This indicates that the observed numerical differences in the average increase in clinical crown height, ranging from 0.62 – 0.81 mm in the non-proclined group to 0.74 – 1.04 mm in the proclined group, were not statistically significant. This suggests that the degree of incisor proclination did not lead to a measurably different rate of gingival margin movement over the one year.

3.3 Development of New Gingival Recession

The occurrence of new gingival recession (defined as visibility of the CEJ at T1 in a site that did not have recession at T0) was compared across the three inclination groups.

Table 3. The occurrence of new gingival recessions across groups

Incisor Inclination Group	Number of Incisors Evaluated (N)	New Recession Cases at T1	Percentage of New Recession (%)
Group 1 (Non-Proclined)	96	3	3.1%
Group 2 (Normal Inclination)	152	5	3.3%
Group 3 (Proclined)	96	4	4.2%
Total	344	12	3.5%

The Chi-square test was performed to test for an association between the degree of incisor inclination (categorical groups) and the categorical outcome of developing new gingival recession. The resulting statistical test showed no meaningful association ($p > 0.05$) between the incisor inclination group and the incidence of new gingival recession.

The development of new recession was relatively low and uniform across all groups, suggesting that the degree of proclination was not a major determinant of this outcome in this one year.

4. Discussion

The present prospective cohort study was designed to investigate the widely discussed clinical question regarding the potential risk of labial gingival recession associated with the proclination of mandibular incisors during orthodontic treatment. Over a one-year follow-up period, the primary finding was the absence of a statistically significant association between the degree of mandibular incisor inclination and both the quantitative change in gingival margin position Δ CCH and the qualitative development of new gingival recession. Specifically, the proclined group (inclination $> 101^\circ$) did not exhibit a significantly greater mean apical movement of the gingival margin (Δ CCH) compared to the non-proclined groups. Furthermore, the incidence of new recession cases remained low and comparable across all inclination categories.

Orthodontic tooth movement, especially the proclination of incisors, has long been cited as a potential predisposing factor for gingival recession due to the possible reduction in the thickness of the labial bone plate, which is thought to be essential for gingival tissue support [1, 6]. Our findings, however, align with several contemporary studies and systematic reviews that have failed to establish a strong, direct causal link between incisor proclination and recession [1, 2, 8]. For instance, Kloukos et al. (2025) and Morris et al. (2017) conducted prospective studies that suggested that the overall effect of fixed appliance treatment on recession development is minimal in patients with good periodontal health [2, 8].

The mechanism often hypothesized is the "pushing" of the root apex through the alveolar bone, thinning the overlying soft tissue [9]. Our study suggests that, for movements achieved within one year and under the conditions of this sample, this tipping effect was either insufficient to cause clinical recession or was compensated for by the adaptive capacity of the periodontal tissues. The relatively young mean age of the cohort (35.8 years) may also contribute to the positive outcome, as younger tissues generally possess greater regenerative

potential compared to the older populations where recession is more commonly observed [1, 2].

The results carry important clinical implications for orthodontic planning. While caution regarding excessive incisor movement remains prudent, this data suggests that achieving therapeutic goals, even those requiring moderate proclination, is unlikely to compromise the gingival health of periodontally healthy adult patients within the first year of treatment. Maintaining excellent oral hygiene, controlling inflammation (gingivitis/periodontitis), and using appropriate brushing techniques remain the most critical preventive measures, as these factors are established and potent contributors to recession development [4, 10]. Therefore, careful orthodontic force application combined with strict periodontal maintenance is paramount.

While our study focused on the active treatment phase, the long-term periodontal health of the mandibular incisors is significantly influenced by the subsequent retention phase. The use of fixed orthodontic retainers is standard practice to prevent relapse, particularly in the lower anterior segment. However, the presence of fixed retainers introduces a potential risk factor for gingival inflammation and recession, primarily by complicating oral hygiene [13, 14].

Several systematic reviews indicate that fixed retainers, particularly those that are bonded directly to the lingual surfaces of all incisors, may be associated with increased plaque accumulation and a slight, yet measurable, increase in gingival inflammation metrics (e.g., bleeding on probing, plaque index) compared to removable retainers or no retainers [11, 13]. Bucur et al. (2022) highlighted the importance of proper bonding protocol and meticulous patient compliance in managing retainer-related complications [14]. Therefore, even if the proclination during active treatment does not trigger recession (as suggested by our findings), the retention method selected and the patient's long-term hygiene compliance around the fixed appliance are crucial determinants of whether recession occurs post-treatment [12]. Clinicians must weigh the superior retention efficacy of fixed appliances against the potential need for enhanced periodontal surveillance and hygiene instruction in these patients.

A key limitation of the present study is the relatively short follow-up period of one year. The full biological response to incisor proclination, particularly bone remodelling and long-term gingival stability, may take longer to manifest. Future research should involve:

Longer Follow-up: Studies extending to the end of active treatment and through the retention phase (2-5 years) are necessary to assess the long-term stability of the gingival margin [11-13].

Cone-Beam Computed Tomography (CBCT): The study lacked radiographic assessment of the labial alveolar bone thickness. Future work should integrate CBCT to correlate incisor inclination with actual changes in bone support, which could provide a more direct link (or lack thereof) between movement and recession risk.

Inclusion of Risk Factors: While periodontal health was an inclusion criterion, future models should quantitatively incorporate other known risk factors (e.g., biotype, brushing force, pre-existing inflammation) to better isolate the independent effect of incisor proclination.

5. Conclusion

This one-year prospective cohort study found no statistically significant correlation between the degree of mandibular incisor proclination during orthodontic treatment and the development of new labial gingival recession or the apical displacement of the gingival margin. These findings reinforce the notion that, in patients with good baseline periodontal health, moderate incisor movement is safe. Emphasis must continue to be placed on maintaining meticulous oral

hygiene and controlling periodontal inflammation throughout orthodontic treatment, including careful selection and maintenance of retention appliances.

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RELATIONSHIP BETWEEN PREMATURE LOSS OF PRIMARY TEETH AND THE INCIDENCE OF ERUPTION DISTURBANCES OF PERMANENT CANINES

Associate Prof. Sorana Maria BUCUR Ph.D.¹, University Assist.Prof. Alexandra Camelia POGĂCIAN-MAIER², PhD Student, Prof.univ. Alexandrina MUNTEAN Ph.D.³

¹Department of Dentistry, Faculty of Medicine, Dimitrie Cantemir University of Târgu Mureş, 540545 Târgu Mureş, România;

²Doctoral School, University of Medicine and Pharmacy "Iuliu Hațieganu" Cluj-Napoca, 400347 Cluj-Napoca, Romania.;

³Department of Paediatric Dentistry, Iuliu Hatieganu University of Medicine and Pharmacy, 31 A. Iancu Street, 400083 Cluj-Napoca, Romania;

Corresponding author: Alexandra Camelia Pogăcian-Maier: alemaier10@yahoo.com

Abstract

Background: Premature loss of primary teeth is a frequent event in paediatric dentistry and is suspected to influence the normal eruption sequence of permanent successors. The permanent canines, due to their long and complex eruption path, are particularly susceptible to disturbances such as ectopic eruption or impaction. This study aimed to evaluate the relationship between premature loss of primary teeth and the incidence of eruption disturbances of permanent canines. **Materials and Methods:** A cross-sectional study was conducted on 103 children (aged 8–13 years) attending a university dental clinic. Clinical and panoramic radiographic examinations were performed to assess the eruption status of permanent canines. Data on premature primary tooth loss (defined as loss ≥ 12 months before the expected exfoliation time) were collected from dental records. Statistical analyses included chi-square tests and logistic regression to evaluate associations between premature tooth loss and canine eruption disturbances, controlling for age, sex, and arch length. **Results:** Premature loss of one or more primary teeth occurred in 29.4% of participants. Eruption disturbances of permanent canines were identified in 17.7% of the total sample, with a significantly higher prevalence (32.1%) among those with premature primary tooth loss compared to those with normal exfoliation (12.5%; $p < 0.001$). Logistic regression revealed that premature loss of primary canines or first molars increased the risk of canine eruption disturbance by 2.8 times (95% CI: 1.9–4.3). The maxillary arch showed a higher incidence of disturbances than the mandibular arch. **Conclusion:** The premature loss of primary teeth, particularly canines and first molars, is strongly associated with an increased risk of eruption disturbances of permanent canines. Early detection and timely space maintenance minimize such complications and reduce the need for complex orthodontic interventions.

Keywords: premature tooth loss; primary teeth; eruption disturbance; permanent canines; ectopic eruption; space maintenance; paediatric dentistry

1. Introduction

The development of the permanent dentition is a complex and highly regulated process that depends on the timely exfoliation of primary teeth, preservation of arch length, and coordinated skeletal growth [1,2]. Premature loss of primary teeth remains a common clinical finding in paediatric dentistry, most often resulting from extensive dental caries, traumatic injuries, or early extractions due to infection [3-5]. When primary teeth are lost before their normal exfoliation time, the balance between eruptive forces and available space within the dental arch may be disrupted, potentially leading to malocclusion and altered eruption patterns of permanent successors [3,6].

Among the permanent teeth, canines are particularly vulnerable to eruption disturbances. Their long developmental period, deep initial position within the maxilla or mandible, and complex eruption trajectory make them sensitive to changes in arch length and guidance provided by primary predecessors [7-9]. Disturbances such as ectopic eruption, delayed eruption, or impaction of permanent canines are frequently associated with functional limitations, esthetical concerns, and the need for complex orthodontic or surgical interventions [9,10].

Although previous studies have suggested a relationship between premature primary tooth loss and altered eruption of permanent teeth, the evidence remains inconsistent, particularly with respect to permanent canines [8-10]. Understanding this association is essential for establishing preventive strategies, including early diagnosis, space maintenance, and interceptive orthodontic care. Therefore, the present study aimed to evaluate the relationship between premature loss of primary teeth and the incidence of eruption disturbances of permanent canines in a paediatric population.

2. Materials and Methods

Study Design and Sample

A cross-sectional observational study was conducted at a university-based paediatric dental clinic. The study population consisted of 103 children aged between 8 and 13 years who attended the clinic for routine dental examination or treatment. This age range was selected to correspond with the expected eruption period of permanent canines. Children with systemic conditions affecting tooth development, craniofacial syndromes, or a history of previous orthodontic treatment were excluded.

Clinical and Radiographic Assessment

All participants underwent a comprehensive clinical examination to assess the presence, position, and eruption status of permanent canines. Panoramic radiographs were evaluated to confirm clinical findings and to identify ectopic eruption paths, delayed eruption, or impaction. Eruption disturbance was defined as deviation from the normal eruption path, asymmetry compared to the contralateral tooth, or lack of eruption beyond the expected chronological age.

Assessment of Premature Primary Tooth Loss

Dental records were reviewed to identify cases of premature loss of primary teeth. Premature loss was defined as exfoliation or extraction occurring at least 12 months earlier than the expected physiological exfoliation time for that tooth. Particular attention was given to the premature loss of primary canines and first molars due to their role in space maintenance and eruption guidance.

Statistical Analysis

Descriptive statistics were used to summarize demographic data and prevalence rates. The chi-square test was applied to evaluate associations between premature primary tooth loss and eruption disturbances of permanent canines. Logistic regression analysis was performed to estimate the odds ratio of eruption disturbances associated with premature tooth loss while controlling for age, sex, and arch length. Statistical significance was set at $p < 0.05$.

3. Results

Of the 103 children included in the study, 29.4% exhibited premature loss of one or more primary teeth. Eruption disturbances of permanent canines were identified in 17.7% of the total sample. A significantly higher prevalence of eruption disturbances was observed among children with premature primary tooth loss (32.1%) compared to those with normal exfoliation patterns (12.5%) (Figure 1). This association was statistically significant ($p < 0.001$).

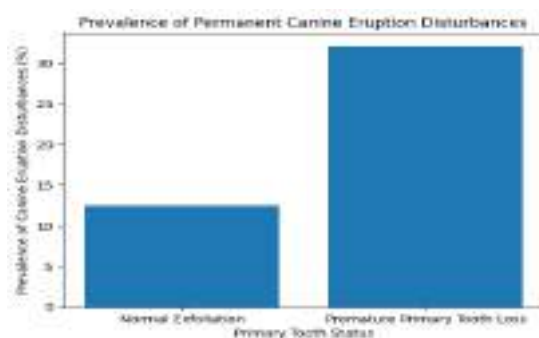


Figure 1. Prevalence of permanent canine eruption disturbances according to primary tooth exfoliation status

Logistic regression analysis demonstrated that premature loss of primary canines or first molars increased the risk of permanent canine eruption disturbance by approximately 2.8 times (95% confidence interval: 1.9–4.3). The maxillary arch showed a higher frequency of eruption disturbances than the mandibular arch, particularly in cases involving premature loss of maxillary primary canines. Among children presenting with eruption disturbances of permanent canines, 68.4% involved the maxillary arch, whereas only 31.6% affected the mandibular arch (Figure 2).

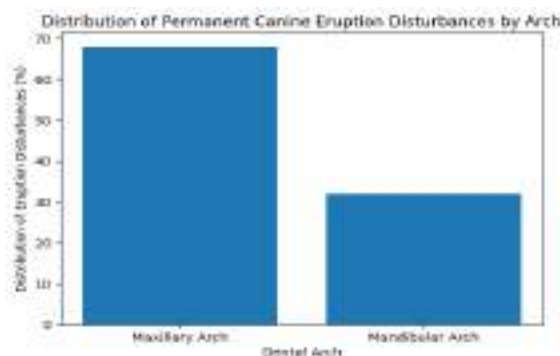


Figure 2. Distribution of permanent canine eruption disturbances by dental arch

No statistically significant differences were observed with respect to sex. Age showed a modest influence, with older children within the sample more likely to present clinically detectable eruption disturbances.

4. Discussion

The present study demonstrates a clear association between premature loss of primary teeth and eruption disturbances of permanent canines. Children who experienced early loss of primary teeth, particularly primary canines and first molars, showed a significantly higher prevalence of ectopic eruption, delayed eruption, or impaction of permanent canines compared to those with physiological exfoliation. These findings support the hypothesis that primary teeth play a crucial role in maintaining arch length and providing eruptive guidance for their permanent successors [11,12].

The increased susceptibility of permanent canines to eruption disturbances can be attributed to their prolonged developmental timeline and complex eruption pathway. In the maxillary arch, permanent canines develop high within the alveolar bone and require adequate space and guidance to erupt into their correct position. Premature loss of adjacent primary teeth may allow mesial migration of posterior teeth and collapse of arch length, thereby altering the eruption trajectory of the canine. This mechanism likely explains the higher incidence of disturbances observed in the maxilla compared to the mandible [13-15].

The results of this study are consistent with previous literature reporting a relationship between premature primary tooth loss and malocclusion, crowding, and ectopic eruption [16,17]. However, some earlier studies have reported conflicting outcomes, possibly due to variations in study design, age ranges, and definitions of premature tooth loss. By applying a clear temporal definition for premature loss and focusing specifically on permanent canines, the present study contributes additional clarity to this ongoing debate.

The lack of significant sex-related differences suggests that eruption disturbances related to premature tooth loss are primarily influenced by local environmental factors rather than biological sex. The modest age-related trend observed may reflect increased clinical detectability of eruption disturbances as children approach the expected eruption age of permanent canines [15-18].

From a clinical perspective, these findings highlight the importance of preserving primary teeth whenever possible through preventive and restorative care. When premature loss is unavoidable, the timely placement of space maintainers and close radiographic monitoring becomes essential to prevent unfavorable eruptive outcomes. Early interceptive orthodontic

measures may reduce the severity of canine displacement and decrease the need for more invasive treatment in adolescence. Despite its strengths, this study has certain limitations. The cross-sectional design does not allow for causal inference, and the sample size, while adequate for detecting significant associations, may limit generalizability. Longitudinal studies with larger populations are needed to further elucidate the temporal relationship between premature primary tooth loss and permanent canine eruption patterns.

5. Conclusion

The findings indicate a strong association between premature loss of primary teeth and eruption disturbances of permanent canines. Primary canines and first molars appear to play a critical role in maintaining arch integrity and guiding normal canine eruption. Their early loss significantly increases the likelihood of ectopic eruption or impaction of permanent canines, particularly in the maxillary arch. These results emphasize the importance of preventive dental care aimed at preserving primary teeth until their natural exfoliation. When premature loss is unavoidable, early diagnosis and timely implementation of space maintenance strategies are essential to reduce the risk of eruption disturbances. Incorporating routine radiographic monitoring and interceptive orthodontic measures may minimize the need for complex treatments later in adolescence. Overall, proactive management of premature primary tooth loss represents a key component in promoting optimal permanent canine eruption and long-term occlusal health.

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FULLY DIGITAL WORKFLOW FOR THE REHABILITATION OF THE COMPLETELY EDENTULOUS PATIENT: ENHANCING EFFICIENCY AND REDUCING PATIENT ANXIETY

Lecturer Cosmin BIDA Ph.D., Simona BIDA, Dana Gabriela BUDILĂ

“Grigore T. Popa” University of Medicine and Pharmacy, 700115 Iasi, Romania
Corresponding author: Simona BIDA: drsimonabida@yahoo.com

Abstract

The BARI 2.0 technique represents a fully digital, AI-assisted workflow for the complex rehabilitation of completely edentulous patients. Originating from the evolution of the classical BARI protocol, this approach digitally transfers the intermaxillary and occlusal relationships from removable CAD/CAM dentures to implant-supported hybrid prostheses fabricated through 3D printing. By integrating artificial intelligence in the diagnostic, design, and manufacturing phases, BARI 2.0 enhances clinical accuracy, reduces chairside time, and significantly diminishes patient anxiety throughout the treatment process. The workflow leverages intraoral scanning, guided surgery, and STL file superimposition—steps that can be algorithmically optimized through AI-driven prediction and error correction. Beyond its clinical implications, this method embodies a paradigm shift in dental education, where digital literacy and AI-based simulation tools reshape the learning curve for future practitioners. The presented case illustrates not only the functional and aesthetic predictability of the BARI 2.0 workflow but also its educational potential as a bridge between traditional prosthodontics and intelligent, data-driven dentistry.

Keywords: Artificial Intelligence; Digital Dentistry; BARI 2.0; Implant-Supported Prosthesis; 3D Printing; Guided Surgery; Clinical Education; Patient-Centered Innovation

1. Introduction

In the last decade, digital dentistry has transformed from an experimental adjunct to a clinical standard of care. CAD/CAM technology, 3D printing, and AI-assisted planning have streamlined prosthetic fabrication and improved predictability in implant-supported rehabilitations [1,2]. Among full-arch edentulous cases, where precision and patient compliance are critical, these technologies allow for faster, more reproducible results while simultaneously reducing patient stress and procedural complexity [3].

The BARI 2.0 technique represents an evolution from the original *BARI 1.0* method developed in Italy [4]. Initially designed as an analogue system for transferring prosthetic relationships from removable dentures to fixed implant-supported structures, the 2.0 version has transitioned entirely into a fully digital workflow. The integration of artificial intelligence enhances virtual planning accuracy, facilitates guided surgery, and automates data alignment between intraoral scans and CBCT images [5].

AI also introduces a paradigm shift in education, allowing learners to simulate treatment outcomes, detect planning errors, and analyze performance metrics in real time [6]. Within this framework, BARI 2.0 is not only a clinical technique but also a didactic model, illustrating how digital workflows can strengthen both patient care and professional training.

2. Materials and Methods

2.1 Patient Selection and Clinical Context

A 57-year-old male patient presented with complete edentulism in both arches. The patient was classified as ASA I (American Society of Anesthesiologists) and reported no systemic pathologies. After several years of wearing removable dentures fabricated through CAD/CAM milling from PMMA, he sought a more stable and permanent solution. The patient's prior adaptation to digital removable prostheses made him an ideal candidate for transition to a fully guided, implant-supported rehabilitation [7].

2.2 Digital Diagnostic Workflow

The existing removable prostheses, already designed in CAD software, were used as diagnostic templates. STL files of the dentures were imported into coDiagnostiX for virtual planning. AI-supported algorithms allowed automatic detection of alveolar bone contours and optimized implant angulation relative to prosthetic space and occlusal load [8].

Duplicate dentures were printed using radiotransparent resin and embedded with radiopaque reference markers to generate a radiographic guide. Following CBCT acquisition, both arches were virtually aligned to the patient's prosthetic design.

2.3 Guided Surgical Protocol

A mucosa-supported surgical guide was printed with three fixation pins to ensure intraoral stability. The guide incorporated occlusal reference stops that preserved the patient's habitual vertical dimension during fixation. Six implants, specifically designed for immediate loading and enhanced osteointegration, were placed according to the digital plan.

After guide removal, multiunit abutments were positioned, and an intraoral scan was performed using a prosthetic guide with six scan body openings. AI-enhanced stitching algorithms were employed to overcome common errors in scanning edentulous arches, such as surface uniformity and lack of anatomic landmarks [9].

2.4 Prosthetic Design and Fabrication

The following datasets were generated:

- (1) mandibular scan with implants and prosthetic guide;
- (2) opposing maxillary denture scan;
- (3) mandibular diagnostic denture file; and
- (4) occlusal relationship record.

AI-assisted software automatically merged these files through point-cloud registration. The final hybrid prosthesis was 3D printed from high-density PMMA reinforced with titanium cylinders and delivered on the same day.

3. Results

The definitive implant-supported prosthesis was delivered within 24 hours after surgery. The occlusal contacts were virtually identical to those of the diagnostic denture, eliminating the need for major chairside adjustments.

At one-year follow-up, the patient demonstrated full functional adaptation and stable soft tissue conditions around the implants. AI integration in each stage of the workflow led to:

- enhanced precision of implant positioning (deviation < 0.5 mm compared to the digital plan);
- 20–30% reduction in total treatment time;
- improved patient satisfaction through visual digital previews and simulation;
- reduction in anxiety levels, as confirmed by visual analogue scale (VAS) self-reporting, consistent with previous studies linking digital workflows to psychological comfort [10,11].

Clinicians reported increased confidence in intraoral scanning and virtual articulation accuracy, while the digital database allowed longitudinal monitoring and continuous refinement of design parameters.

4. Discussion

4.1 Clinical Implications

Immediate loading protocols for edentulous patients traditionally face challenges related to the accurate transfer of centric relation and vertical dimension [12]. The BARI 2.0 technique overcomes these limitations by digitally linking diagnostic and final prosthetic phases, thus minimizing cumulative errors.

The use of AI-guided algorithms ensures that each design iteration is automatically validated for biomechanical feasibility, eliminating subjectivity and reducing dependence on analogue articulators [13]. Similar digital workflows have been shown to enhance reproducibility and decrease misfit rates of implant frameworks by up to 40% compared with traditional methods [14].

4.2 Psychological and Educational Perspectives

From a patient standpoint, AI and digital visualization serve as *anxiolytic interfaces*—tools that transform fear of the unknown into understanding through visual feedback and predictive simulation [15]. The ability to preview outcomes and treatment stages has measurable effects on reducing dental anxiety, particularly among edentulous or previously traumatized individuals [16].

Educationally, the BARI 2.0 workflow introduces an AI-enhanced, problem-based learning framework. Students can analyze STL datasets, perform guided virtual implant placements, and evaluate the occlusal outcomes predicted by AI algorithms [17]. These simulations accelerate cognitive integration of digital prosthodontics, allowing future clinicians to focus more on critical thinking than manual repetition [18].

Furthermore, the integration of digital case libraries in university curricula enables the use of *machine learning* to track student performance, compare outcomes, and personalize learning trajectories—an approach consistent with the principles of adaptive education [19].

4.3 Technological and Future Directions

The evolution of the BARI 2.0 system suggests that future iterations could incorporate *deep neural networks* capable of automatic segmentation of CBCT data, AI-based implant path optimization, and real-time feedback during surgical navigation [20].

As cloud-based collaboration expands, patient data could be securely shared between surgical, prosthetic, and laboratory teams, creating an integrated AI ecosystem for complex rehabilitations. Beyond clinical applications, this data-driven environment represents a living educational archive for ongoing research, student learning, and clinical auditing.

5. Conclusions

The BARI 2.0 technique demonstrates how artificial intelligence and digital workflows can merge into a single, efficient, and patient-centered model for oral rehabilitation. It allows for precision in immediate loading cases, reduces anxiety through digital predictability, and enhances interdisciplinary collaboration.

From an educational standpoint, it provides a structured framework for developing digital competencies among dental students and residents. AI thus becomes both a clinical and pedagogical catalyst—reshaping prosthodontics into an evidence-based, data-driven discipline.

The integration of AI into prosthetic dentistry marks not merely a technological evolution but a philosophical one: the shift from manual craftsmanship to intelligent co-creation between human expertise and digital cognition.

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GERANIUM OIL AS A BIOACTIVE AGENT IN THE PREVENTION OF DENTURE STOMATITIS: EXPERIMENTAL EVALUATION, PSYCHOSOCIAL CORRELATES, AND THERAPEUTIC PERSPECTIVES

University Teaching Assistant, PhD Student Dorin Ioan COCOȘ¹; Prof. Mariana PĂCURAR, Ph.D.²; Assoc. Prof. Sorina-Mihaela BĂLAN, Ph.D.³; Prof. Kamel EARAR, Ph.D.¹; Assoc. Prof. Ramona Diana FEIER, Ph.D.³

¹Faculty of Dental Medicine, "Dunărea de Jos" University, 800008 Galați, Romania;

²"George Emil Palade" University of Medicine, Pharmacy, Science and Technology, Târgu Mureș, Romania, Faculty of Dental Medicine;

³Faculty of Psychology/ Faculty of Medicine, "Dimitrie Cantemir" University, 540545 Târgu Mureș, Romania

Corresponding author: Kamel EARAR, kamel.earar@ugal.ro, Sorina-Mihaela BĂLAN, bsorinamihaela@yahoo.com

Abstract

Geranium essential oil (*Pelargonium graveolens*) has emerged as a bioactive natural compound with significant antimicrobial, anti-inflammatory, and anxiolytic properties, offering an integrative therapeutic potential in oral health management. This paper explores its dual relevance — both in preventing and managing denture stomatitis and in reducing psychological distress and anxiety associated with oral discomfort and prosthetic rehabilitation. Experimental evidence confirms the oil's antifungal efficacy against *Candida albicans*, through disruption of fungal membranes and inhibition of biofilm formation on acrylic denture surfaces. Its anti-inflammatory effects, mediated by modulation of cytokine expression and oxidative stress reduction, facilitate mucosal healing and patient comfort. Moreover, the psychological dimension is emphasized: oral pain and aesthetic concerns frequently trigger anxiety, affecting adherence to treatment and overall well-being. The pleasant aroma and mild anxiolytic action of geranium oil may contribute to emotional relaxation during dental care, supporting an interdisciplinary dentist–psychologist approach in patient management. Future studies should address the integration of such natural agents into holistic therapeutic protocols, optimizing both somatic and psychosocial outcomes for patients with denture-related lesions.

Keywords: geranium oil; denture stomatitis; *Candida albicans*; oral mucosa; anxiety; dentist–psychologist approach

1. Chemical and Bioactive Profile of *Pelargonium Graveolens* Essential Oil

Pelargonium graveolens essential oil (geranium oil) has attracted increasing scientific interest due to its complex chemical composition and broad spectrum of bioactive properties, which underpin its therapeutic potential in inflammatory and infectious conditions. Extracted primarily from the aerial parts of the plant, the oil is characterized by a rich mixture of monoterpenoids and sesquiterpenoids, whose qualitative and quantitative distribution depends on geographic origin, cultivation conditions, and extraction methods [1-3]. This compositional variability is clinically relevant, as it directly influences pharmacological efficacy and safety.

The major constituents of geranium oil typically include citronellol, geraniol, linalool, isomenthone, and citronellyl formate, compounds recognized for their antimicrobial, antioxidant, and anti-inflammatory actions [2,3]. Studies focusing on chemical markers have demonstrated that these alcohol-based monoterpenes are primarily responsible for membrane-disruptive effects on microbial cells, leading to altered permeability, leakage of intracellular contents, and metabolic inhibition [3]. Such mechanisms are fundamental to the oil's broad antimicrobial spectrum, which extends to bacteria, fungi, and viruses [2-5].

Beyond its antimicrobial activity, geranium oil exhibits significant antioxidant capacity, attributable to its ability to scavenge reactive oxygen species and modulate oxidative stress pathways [6,7]. Oxidative stress plays a central role in mucosal inflammation and delayed tissue repair; therefore, the antioxidant profile of geranium oil provides a rational basis for its application in inflammatory oral pathologies. Experimental data indicate that the oil can reduce lipid peroxidation and enhance endogenous antioxidant defenses, contributing to cellular protection and tissue homeostasis [7-11].

Anti-inflammatory effects constitute another critical dimension of geranium oil's bioactivity. In vitro and in vivo models have demonstrated its capacity to downregulate pro-inflammatory mediators, including nitric oxide, prostaglandins, and key cytokines involved in chronic inflammatory cascades [12]. These effects appear to be mediated through interference with cyclooxygenase pathways and modulation of macrophage activity, resulting in reduced edema and inflammatory cell infiltration [12,13]. Such mechanisms are particularly relevant for conditions characterized by persistent mucosal inflammation, where conventional anti-inflammatory agents may be limited by adverse effects.



Figure 1. Integrative conceptual representation illustrating the association between denture stomatitis, *Candida albicans* infection, and anxiety modulation through the use of *Pelargonium graveolens* essential oil. Source: Stock medical illustration; adapted by the authors.

The figure 1 highlights the interrelation between oral pathology, psychological distress, and complementary therapeutic approaches, illustrating the psychosomatic interplay between fungal pathology, anxiety, and the complementary use of essential oils within a holistic health framework.

The synergistic potential of geranium oil with other bioactive compounds or pharmacological agents has also been explored. Evidence suggests that combinations of geranium oil with antibiotics or antioxidants may enhance antimicrobial efficacy and reduce required drug dosages, potentially mitigating resistance development and systemic toxicity [14-16]. This synergism highlights the oil's role not merely as an alternative, but as a complementary therapeutic agent.

From a safety perspective, geranium oil is generally considered well tolerated when used at appropriate concentrations; however, cytotoxicity and reproductive toxicity have been reported at higher doses or with prolonged exposure [17]. These findings underscore the necessity of controlled formulations and standardized dosing regimens, particularly for clinical applications involving repeated or long-term use. Advanced delivery systems, such as lipid vesicles or niosomal carriers, have been proposed to optimize bioavailability while minimizing adverse effects [1].

In summary, the chemical complexity of *Pelargonium graveolens* essential oil underlies a multifaceted bioactive profile, encompassing antimicrobial, antioxidant, and anti-inflammatory effects. These properties, supported by experimental and pharmacological evidence [1-15], provide a robust scientific rationale for further investigation of geranium oil as a bioactive agent in oral medicine and beyond.

2. Pathophysiology of Denture Stomatitis: Microbial, Inflammatory and Psychosocial Determinants

Denture stomatitis represents a multifactorial inflammatory condition of the oral mucosa, predominantly affecting edentulous patients wearing removable prostheses. Its etiopathogenesis is classically linked to local microbial imbalance, mechanical irritation, and impaired mucosal defense; however, growing evidence highlights the contribution of psychosocial and neuroinflammatory factors to disease persistence and therapeutic response [15-18]. Chronic oral discomfort, burning sensation, and aesthetic dissatisfaction frequently induce anxiety, which in turn may exacerbate inflammatory pathways through stress-related immunomodulation.

From a microbial perspective, *Candida albicans* colonization of acrylic denture surfaces remains a central pathogenic factor, facilitating biofilm formation and sustained mucosal inflammation. Clinical observations confirm that antifungal therapy alone is often insufficient, particularly when local inflammatory reactivity and patient-related factors are not addressed [19]. Persistent inflammation leads to epithelial atrophy, vascular congestion, and increased mucosal permeability, creating a self-perpetuating cycle of infection and tissue damage.

Psychological stress and anxiety have been shown to influence inflammatory responses and pain perception, modulating cytokine release and oxidative stress at the mucosal level [15,18]. In this context, sensory stimuli such as odor perception gain clinical relevance. The olfactory characteristics of rose-scented geranium have been associated with emotional modulation and relaxation, suggesting a potential indirect benefit in reducing stress-related amplification of oral symptoms [16]. These effects may improve patient compliance with prosthetic hygiene and therapeutic regimens.

Safety considerations are essential when addressing chronic conditions requiring repeated exposure to bioactive agents. While geranium oil demonstrates low toxicity at therapeutic doses, experimental data indicate potential cytotoxic or reproductive effects at higher concentrations, emphasizing the importance of controlled topical use [17,20]. Interestingly,

studies exploring the interaction of geranium oil with pharmacological agents reveal modulatory effects on cellular viability and drug sensitivity, underscoring its biological potency and the need for precise dosing [21].

Overall, denture stomatitis should be understood as a complex condition arising from the interaction of microbial, inflammatory, and psychosocial determinants. This integrated perspective provides the rationale for therapeutic strategies that address not only fungal eradication but also mucosal inflammation, patient anxiety, and overall quality of life [15-21].

3. Experimental and Clinical Evidence of *Geranium* Oil in the Management of Denture Stomatitis

Experimental and clinical investigations provide convergent evidence supporting the efficacy of *Pelargonium graveolens* essential oil as a bioactive agent in the prevention and management of denture stomatitis. The therapeutic rationale is primarily grounded in its pronounced antifungal activity against *Candida albicans*, the key etiological agent implicated in prosthesis-related mucosal inflammation. In vitro studies have consistently demonstrated that geranium oil disrupts fungal cell membrane integrity, interferes with ergosterol-dependent pathways, and inhibits yeast-to-hyphae transition, a critical virulence factor for mucosal invasion and biofilm maturation [10,11].

Biofilm formation on acrylic denture bases represents a major clinical challenge, as mature biofilms confer resistance to conventional antifungal agents and mechanical cleansing. Experimental data indicate that geranium oil significantly reduces *Candida albicans* adhesion and biofilm biomass on polymeric surfaces, suggesting its utility both as a preventive coating agent and as a component of denture hygiene protocols [10]. Molecular docking and in silico analyses further support these findings, revealing strong binding affinities between key oil constituents and fungal enzymatic targets involved in cell wall synthesis and oxidative stress regulation [11].

Beyond its antifungal properties, geranium oil exhibits relevant anti-inflammatory effects that directly address the mucosal component of denture stomatitis. Experimental models have shown downregulation of inflammatory mediators, reduction of nitric oxide production, and attenuation of edema in inflamed tissues following topical application [12]. These effects are clinically significant, as persistent inflammation contributes to epithelial thinning, vascular congestion, and patient discomfort even after microbial load reduction. Antioxidant activity further enhances mucosal recovery by limiting oxidative tissue damage and supporting epithelial repair mechanisms [14].

Clinical evidence, although limited, reinforces the translational potential of these experimental findings. A clinical evaluation assessing the topical application of *Pelargonium graveolens* essential oil in patients with denture stomatitis reported significant improvement in clinical signs, including erythema and mucosal sensitivity, alongside a reduction in fungal colonization [19]. Importantly, patient tolerance was favourable, with minimal adverse reactions when appropriate concentrations were employed, underscoring its suitability for intraoral use under controlled conditions.

Advances in pharmaceutical formulation have expanded the therapeutic perspectives of geranium oil. Encapsulation strategies using lipid-based vesicles and niosomal systems have been shown to enhance stability, controlled release, and mucosal penetration of essential oils, while reducing cytotoxicity [1]. Such delivery systems may be particularly advantageous in

chronic conditions like denture stomatitis, where prolonged contact with the mucosa is required for sustained therapeutic effect.

Collectively, available experimental and clinical data support the role of geranium oil as a multifunctional agent capable of targeting both microbial and inflammatory components of denture stomatitis. Its integration into modern, evidence-based therapeutic strategies warrants further controlled clinical trials to optimize dosing, formulation, and long-term safety [10-12,14,19].

Table 1. Bioactive constituents of *Pelargonium graveolens* essential oil and mechanistic relevance in denture stomatitis

Bioactive compound/fraction	Dominant biological activity	Mechanism of action	Targeted pathological process	Clinical relevance in denture stomatitis	References
Citronellol	Antifungal, antibacterial	Disruption of fungal cell membrane integrity	<i>Candida albicans</i> viability and adhesion	Reduction of fungal load on denture surfaces	[2,3], [10,11]
Geraniol	Antifungal, anti-inflammatory	Inhibition of ergosterol synthesis	Biofilm formation and hyphal transition	Prevention of persistent <i>Candida</i> biofilms	[3,10,11]
Linalool	Anti-inflammatory, antioxidant	Downregulation of pro-inflammatory mediators; ROS scavenging	Mucosal inflammation and oxidative stress	Enhancement of mucosal healing	[7,12,14]
Monoterpene-rich fraction	Broad-spectrum antimicrobial	Synergistic membrane-disruptive effects	Mixed microbial biofilms	Adjunctive antimicrobial effect	[2,5,10]
Whole essential oil	Multifunctional bioactivity	Multi-target microbial and host modulation	Microbial-inflammatory pathology	Comprehensive management	[10,12,14,19]

Table 1 summarizes the major bioactive compounds of *Pelargonium graveolens* essential oil, their dominant biological activities, underlying mechanisms of action, and direct relevance to the prevention and management of denture stomatitis, as supported by experimental and clinical evidence.

4. Psychosocial Impact of Denture Stomatitis and the Anxiolytic Potential of *Geranium* Oil

Denture stomatitis extends beyond its local inflammatory manifestations, exerting a substantial psychosocial burden on affected patients. Chronic oral discomfort, burning sensations, and altered aesthetics associated with ill-fitting or contaminated prostheses frequently impair quality of life and may generate anxiety, emotional distress, and reduced self-esteem. These psychological factors can negatively influence oral hygiene practices and adherence to therapeutic recommendations, thereby perpetuating disease chronicity [15,18]. Consequently, effective management of denture stomatitis requires an integrative approach that addresses both somatic and psychosocial dimensions.

Emerging evidence supports the role of olfactory stimulation and aromatherapy in modulating emotional states and stress-related physiological responses. Geranium essential oil, characterized by a pleasant rose-like aroma, has been shown to exert anxiolytic effects through central nervous system pathways, likely involving limbic system activation and autonomic nervous system modulation [15,18]. Clinical trials conducted in non-dental settings, including patients with acute myocardial infarction and women in labor, have demonstrated significant reductions in anxiety scores and improvements in physiological parameters following inhalation of geranium aroma [15,18]. Although indirect, these findings provide a biologically plausible framework for its application in dental care, where anxiety is a common barrier to successful treatment.

Odor perception studies further elucidate the sensory properties of *Pelargonium graveolens*, highlighting its capacity to evoke positive emotional responses and promote relaxation [16]. In the context of prosthetic dentistry, such effects may improve patient comfort during clinical procedures and enhance acceptance of adjunctive topical therapies. Reduced anxiety may also attenuate stress-induced inflammatory responses, potentially contributing to improved mucosal healing and symptom relief.

Safety considerations remain essential when integrating aromatherapeutic interventions into clinical practice. While geranium oil is generally well tolerated at low concentrations, excessive or prolonged exposure may pose risks, particularly in vulnerable populations [17]. Additionally, its demonstrated bioactivity at the cellular level, including interactions with pharmacological agents, underscores the importance of standardized formulations and controlled application protocols [20,21].

In summary, the psychosocial dimension of denture stomatitis represents a clinically relevant target for adjunctive therapeutic strategies. The anxiolytic and sensory properties of geranium oil offer a complementary benefit that may enhance patient experience, treatment compliance, and overall therapeutic outcomes. Incorporating such approaches within an interdisciplinary dentist–psychologist framework aligns with contemporary patient-centered models of care [15-21].

Table 2. Psychosocial determinants of denture stomatitis and therapeutic implications of *Pelargonium graveolens* essential oil

Psychosocial factor	Clinical manifestation	Pathophysiological link	Role of geranium oil	Therapeutic implication	References
Anxiety related to oral discomfort	Increased pain perception, avoidance	Stress-induced immune modulation	Anxiolytic olfactory effect	Improved tolerance and compliance	[15,18]
Aesthetic dissatisfaction	Reduced self-esteem	Psychoneuroimmune amplification	Emotional relaxation	Enhanced quality of life	[16,18]
Inflammation-associated stress	Delayed healing	Oxidative stress signaling	Antioxidant and anti-inflammatory action	Support of mucosal recovery	[14,15]
Poor therapeutic compliance	Recurrent stomatitis	Behavioral response to anxiety	Improved patient acceptance	Better hygiene adherence	[15,19]
Safety concerns	Fear of adverse effects	Awareness of bioactivity	Need for controlled dosing	Safe interdisciplinary use	[17,20,2]

Table 2 integrates psychosocial factors associated with denture stomatitis and highlights the potential role of *Pelargonium graveolens* essential oil in modulating anxiety, treatment compliance, and patient-centered outcomes.

5. Therapeutic Perspectives and Interdisciplinary Implications

The integration of *Pelargonium graveolens* essential oil into contemporary therapeutic strategies for denture stomatitis reflects a broader shift toward holistic, patient-centered care that addresses both biological and psychosocial determinants of oral disease. Given its documented antifungal, anti-inflammatory, antioxidant, and anxiolytic properties, geranium oil represents a promising adjunctive agent capable of complementing conventional prosthetic hygiene measures and antifungal therapies [10-12,14,15].

From a clinical perspective, geranium oil may be incorporated into preventive and therapeutic protocols in multiple forms, including topical applications, denture cleansing solutions, or controlled-release formulations designed to prolong mucosal contact and enhance bioavailability [1,19]. Such approaches are particularly relevant in patients with recurrent stomatitis, where long-term antifungal use may be limited by resistance, adverse effects, or poor compliance. The multifunctional profile of geranium oil allows simultaneous targeting of microbial load, mucosal inflammation, and patient discomfort, potentially improving overall treatment outcomes [10,12,19].

Interdisciplinary collaboration constitutes a key therapeutic implication. The interaction between oral pathology and psychological distress underscores the importance of integrating psychological assessment and support into prosthetic rehabilitation. The anxiolytic and sensory properties of geranium oil may facilitate this interface, contributing to reduced treatment-related anxiety and improved patient engagement [15,16,18]. Such an approach aligns with modern models of oral healthcare, in which dentists collaborate with psychologists or other healthcare professionals to optimize quality of life and long-term therapeutic success.

Despite these promising perspectives, several limitations must be acknowledged. Variability in essential oil composition, lack of standardized dosing regimens, and limited large-scale randomized clinical trials restrict the generalizability of current evidence [2,3,17]. Furthermore, the biological potency of geranium oil, including its cytotoxic and modulatory effects at higher concentrations, necessitates cautious formulation and rigorous safety evaluation, particularly for chronic intraoral use [17,20,21].

Future research should focus on well-designed clinical trials assessing efficacy, safety, and patient-reported outcomes, as well as on the development of standardized pharmaceutical formulations tailored for oral applications. Within this framework, geranium oil holds potential as a valuable component of integrative therapeutic protocols for denture stomatitis, bridging biological treatment and psychosocial care [1,10-21].

6. Conclusions

Geranium essential oil (*Pelargonium graveolens*) demonstrates a multifaceted therapeutic profile that effectively targets the microbial, inflammatory, and psychosocial components of denture stomatitis. Experimental and limited clinical evidence support its role as a safe and biologically active adjunct capable of enhancing mucosal healing while reducing fungal colonization and patient discomfort. Integration of geranium oil into standardized,

interdisciplinary treatment protocols may improve both clinical outcomes and quality of life, provided that formulation, dosing, and long-term safety are rigorously validated.

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EFFECTIVENESS OF MINI-IMPLANTS AS AN ANCHORAGE SYSTEM IN THE TREATMENT OF ANGLE CLASS II MALOCCLUSION

Assoc. Prof. Sorana Maria BUCUR Ph.D.¹; PhD Student Cristian COJOCARIU^{2*}; Univ. Teach Assist. Student Mioara DÂRNEA Ph.D.^{3*}; Lecturer Radu Mircea Sireteanu CUCUI Ph.D.¹

¹Department of Dentistry, Faculty of Medicine, Dimitrie Cantemir University of Târgu Mureș, 540545 Târgu Mureș, România;

²Faculty of Dental Medicine, “Dunărea de Jos” University, 800008 Galați, România;

³Faculty of Dental Medicine, “Grigore T. Popa” University of Medicine and Pharmacy, Iasi, 16 Universitatii Str., 700115 Iasi, Romania

Corresponding author: Cristian Cojocariu: cristian_tgm@yahoo.com, Mioara Dârnea: miodar2@yahoo.com

Abstract

Objectives: To evaluate the effectiveness of mini-implant (MI) anchorage compared to conventional anchorage in the orthodontic treatment of skeletal Class II malocclusion. **Materials and Methods:** This prospective clinical study included 64 patients (aged 13–25 years) diagnosed with skeletal Class II malocclusion. Participants were equally divided into two groups: Group 1 (n = 32) treated using conventional anchorage methods (transpalatal arch and headgear) and Group 2 (n = 32) treated with MI anchorage placed in the posterior maxillary region. Pre-treatment and post-treatment cephalometric radiographs were analyzed for angular and linear measurements, including SNA, SNB, ANB, U1-SN, and molar displacement. Statistical analyses were performed using paired t-tests and ANOVA ($p < 0.05$). **Results:** Baseline demographic characteristics were comparable between groups. Both anchorage techniques resulted in significant decreases in SNA and SNB angles after treatment. However, the MI anchorage group exhibited significantly greater posterior movement and intrusion of maxillary incisors and molars ($p < 0.01$). The forward displacement of maxillary first molars was substantially reduced in the MI group compared with the conventional group, indicating superior anchorage control. Furthermore, the MI group demonstrated less molar extrusion and a favorable counterclockwise mandibular rotation, which contributed to improved facial aesthetics. According to the Peer Assessment Rating (PAR) index, 75% of the MI anchorage group showed outcomes classified as “greatly improved,” compared with 47% in the conventional group. **Conclusions:** Mini-implant anchorage provides more efficient and stable anchorage control than conventional methods in the treatment of skeletal Class II malocclusion. It facilitates effective retraction and intrusion of anterior teeth, minimizes molar movement, and improves vertical and sagittal skeletal relationships—yielding superior aesthetic and functional outcomes.

Keywords: mini-implant anchorage; skeletal Class II malocclusion; orthodontic treatment; cephalometric analysis; anchorage control; PAR index.

Introduction

Skeletal Class II malocclusion is one of the most common dentofacial discrepancies encountered in orthodontic practice and is typically characterized by maxillary protrusion, mandibular retrusion, or a combination of both [1,2]. Clinically, it is often associated with increased overjet, facial convexity, and compromised facial aesthetics [1,2]. Successful management of skeletal Class II malocclusion frequently depends on effective anchorage control, particularly when treatment objectives include significant retraction and intrusion of maxillary anterior teeth [2-4].

Conventional anchorage methods, such as transpalatal arches and extraoral headgear, have been widely used to counteract orthodontic reaction forces. However, these approaches rely heavily on patient compliance and often fail to provide absolute anchorage, resulting in undesirable forward movement and extrusion of posterior teeth. Such anchorage loss may compromise both dental alignment and skeletal correction, especially in patients with vertical growth tendencies [5-8].

The development of temporary anchorage devices, particularly orthodontic mini-implants, has revolutionized anchorage management. Mini-implants provide skeletal anchorage that is independent of patient cooperation, minimally invasive, and capable of delivering predictable orthodontic forces. Their use has expanded rapidly, particularly in cases requiring maximum anchorage and precise vertical control [5-10].

Despite increasing clinical acceptance, prospective comparative data evaluating the effectiveness of mini-implant anchorage relative to conventional anchorage systems in skeletal Class II malocclusion remain limited. Therefore, this study aimed to compare the dentoskeletal and occlusal outcomes of mini-implant anchorage and conventional anchorage methods in the orthodontic treatment of skeletal Class II malocclusion.

Materials and Methods

Study Design and Sample

This prospective clinical study was conducted on 64 patients aged between 13 and 25 years who presented with skeletal Class II malocclusion at a university orthodontic clinic. Skeletal Class II malocclusion was defined by an ANB angle greater than 4°. All participants were in the permanent dentition and had no history of previous orthodontic treatment.

Patients with craniofacial syndromes, systemic diseases affecting bone metabolism, missing permanent teeth (excluding third molars), or poor oral hygiene were excluded. Informed consent was obtained from all participants or their legal guardians.

Group Allocation and Treatment Protocol

Participants were equally allocated into two groups:

Group 1 (Conventional Anchorage Group, n = 32): Treated using transpalatal arches combined with cervical or high-pull headgear.

Group 2 (Mini-Implant Anchorage Group, n = 32): Treated using titanium mini-implants placed in the posterior maxillary region between the second premolar and first molar.

All patients were treated with fixed pre-adjusted edgewise appliances using a standardized archwire sequence. In the MI group, orthodontic forces for anterior retraction and vertical control were applied directly from the mini-implants immediately after placement.

Cephalometric and Occlusal Analysis

Standardized lateral cephalometric radiographs were obtained before and after orthodontic treatment. The following measurements were analyzed: SNA, SNB, ANB, U1–SN angle, maxillary molar mesial movement, and maxillary molar extrusion. Occlusal treatment outcomes were assessed using the Peer Assessment Rating (PAR) index, with results categorized as “greatly improved,” “improved,” or “no improvement.”

Statistical Analysis

Data were analyzed using statistical software. Intra-group comparisons were performed using paired t-tests, while inter-group comparisons were conducted using analysis of variance (ANOVA). Statistical significance was set at $p < 0.05$.

Results

Baseline Characteristics

The mean age was 18.0 ± 3.2 years in the conventional anchorage group and 18.3 ± 3.0 years in the mini-implant anchorage group, with no statistically significant difference between groups ($p = 0.68$). Sex distribution was comparable between groups ($p > 0.05$) (Table 1).

Table 1. Baseline demographic characteristics of the study groups

Variable	Conventional Anchorage (n = 32)	Mini-Implant Anchorage (n = 32)	p-value
Age (years, mean $\pm$ SD)	18.0 ± 3.2	18.3 ± 3.0	0.68
Male (%)	56.3	53.1	0.80
Female (%)	43.7	46.9	—

Cephalometric Outcomes

Both groups demonstrated significant reductions in SNA and SNB angles following treatment ($p < 0.05$), indicating an improvement in sagittal skeletal relationships. However, the magnitude of dentoalveolar and vertical changes differed significantly between groups (Table 2). The reduction in U1–SN angle was significantly greater in the mini-implant group, indicating more effective maxillary incisor retraction and intrusion. Forward movement of maxillary first molars was reduced considerably in the MI group (0.7 ± 0.5 mm) compared with the conventional anchorage group (2.6 ± 0.9 mm; $p < 0.001$). Additionally, maxillary molar extrusion was significantly lower in the MI group (0.6 ± 0.4 mm) than in the conventional group (1.9 ± 0.7 mm; $p < 0.001$).

Table 2. Pre- and post-treatment cephalometric measurements

Measurement	Conventional Anchorage	Mini-Implant Anchorage	Between-group <i>p</i> -value
SNA (°)	82.6 ± 2.7 → 81.1 ± 2.5*	82.4 ± 2.8 → 80.6 ± 2.4*	0.21
SNB (°)	76.2 ± 2.4 → 77.4 ± 2.3*	76.0 ± 2.5 → 77.7 ± 2.2*	0.34
ANB (°)	6.4 ± 1.3 → 3.7 ± 1.2*	6.4 ± 1.2 → 2.9 ± 1.1*	0.02
U1-SN (°)	111.0 ± 5.0 → 105.2 ± 4.6*	111.5 ± 4.8 → 97.9 ± 4.1*	<0.001
Maxillary molar mesial movement (mm)	2.6 ± 0.9	0.7 ± 0.5	<0.001
Maxillary molar extrusion (mm)	1.9 ± 0.7	0.6 ± 0.4	<0.001

* Statistically significant intra-group change ($p < 0.05$)

Figure 1 illustrates a comparison of anchorage control and maxillary incisor retraction between conventional anchorage and mini-implant anchorage groups. The mini-implant group demonstrated significantly reduced mesial movement of maxillary first molars and significantly greater incisor retraction, indicating superior anchorage control ($p < 0.001$).

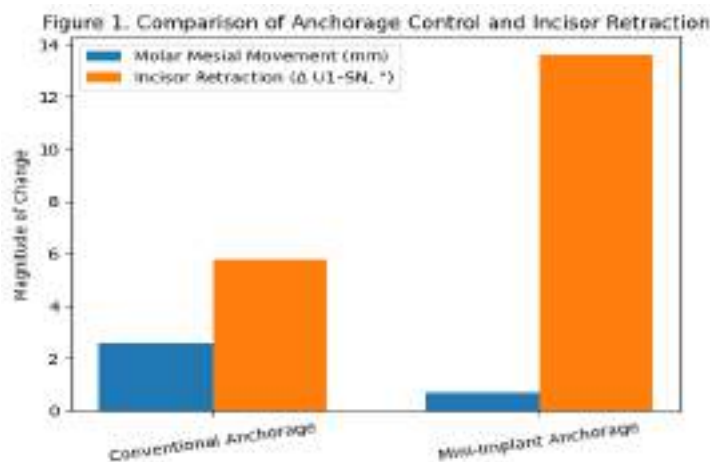


Figure 1. Comparison of Anchorage Control and Incisor Retraction

Occlusal Outcomes

PAR index analysis (Table 3) revealed superior occlusal outcomes in the mini-implant group. Specifically, 75% of patients in the MI group were classified as “greatly improved,” compared with 47% in the conventional anchorage group.

Table 3. Peer Assessment Rating (PAR) index treatment outcomes

Outcome category	Conventional Anchorage (%)	Mini-Implant Anchorage (%)
Greatly improved	46.9	75.0
Improved	37.5	21.9
No improvement	15.6	3.1

Discussion

The findings of this prospective clinical study clearly demonstrate that mini-implant anchorage provides superior anchorage control compared with conventional anchorage

methods in the orthodontic treatment of skeletal Class II malocclusion. While both treatment approaches were effective in improving sagittal skeletal relationships, mini-implant anchorage offered significant advantages in controlling unwanted dental movements and achieving favorable vertical and occlusal outcomes [7,8,10,11,12].

One of the most clinically relevant findings was the marked reduction in maxillary molar mesial movement in the mini-implant group. Conventional anchorage systems depend on dental units and patient compliance, which often leads to anchorage loss. In contrast, mini-implants function as skeletal anchorage units, allowing orthodontic forces to be applied without reciprocal tooth movement. This advantage is particularly important in cases requiring maximum anchorage [13,14].

The significantly greater reduction in the U1–SN angle observed in the MI group reflects improved control over maxillary incisor retraction and torque. This contributed to enhanced overjet reduction and improved facial profile aesthetics. Furthermore, the reduced molar extrusion observed in the MI group facilitated a favorable counterclockwise mandibular rotation, which is associated with improved chin projection and lower facial balance in skeletal Class II patients [15-17].

The superior PAR index outcomes in the MI group underscore the overall clinical effectiveness of mini-implant anchorage. Achieving a higher proportion of cases classified as “greatly improved” reflects not only better tooth positioning but also improved occlusal relationships, which are essential for functional efficiency and long-term stability [5].

Despite these positive findings, certain limitations must be acknowledged. The study did not include a long-term follow-up period to assess post-treatment stability, and the sample included both adolescent and young adult patients, which may have influenced skeletal response. Future studies with larger sample sizes and long-term follow-up are recommended to confirm the stability and generalizability of these results.

Mini-implant anchorage is a more efficient and stable anchorage modality than conventional anchorage methods in the orthodontic treatment of skeletal Class II malocclusion. It enables effective retraction and intrusion of maxillary anterior teeth, minimizes unwanted molar movement, and improves vertical and sagittal skeletal relationships. These advantages result in superior aesthetic and functional outcomes, supporting the routine clinical use of mini-implant anchorage in appropriately selected Class II patients.

Conclusion

Mini-implant anchorage is a more efficient and stable anchorage modality than conventional anchorage methods in the orthodontic treatment of skeletal Class II malocclusion. It enables effective retraction and intrusion of maxillary anterior teeth, minimizes unwanted molar movement, and improves vertical and sagittal skeletal relationships. These advantages result in superior aesthetic and functional outcomes, supporting the routine clinical use of mini-implant anchorage in appropriately selected Class II patients.

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BEE AND NAJA SPECIES VENOMS – INNOVATIVE SOURCES FOR DEVELOPING TOPICAL PHARMACEUTICAL FORMS WITH ANTI-INFLAMMATORY AND ANTI-AGING ACTION

PhD Student Monica DINU¹; Associate Professor, PhD Ramona Diana FEIER²; Professor, PhD Olimpia DUMITRIU BUZIA¹; University Teaching Assistant, PhD Student Irinel LUNGU¹; Associate Professor, PhD Student Cristina BAZBANELA¹; University Teaching Assistant, PhD Student Ana Maria CHIRILOV¹; University Teaching Assistant, PhD Student Dorin Ioan COCOȘ³; Lecturer, PhD Anna BUSUIOC⁴.

¹Centre in the Medical-Pharmaceutical Field, Faculty of Medicine and Pharmacy, “Dunarea de Jos” University of Galati, 800008 Galati, Romania;

²Department of Dentistry, Faculty of Medicine, Dimitrie Cantemir University of Târgu Mureș, 540545 Târgu Mureș, România;

³Faculty of Dental Medicine, “Dunărea de Jos” University, 800008 Galați, Romania;

⁴“Dunarea de Jos” University of Galati, Faculty of Science and Environment, Department of Chemistry, Physics and Environment, Domneasca Street 111, 800201, Galati, Romania

Corresponding author: Dorin Ioan COCOȘ: cdorin1123@gmail.com

Abstract

The growing interest in natural products in modern therapy is attributed to their ability to provide therapeutic effects comparable to synthetic drugs while reducing the incidence of severe adverse reactions associated with conventional treatments. Animal venoms represent complex natural sources of peptides, enzymes, and proteins with high therapeutic potential. Among them, the venoms of *Apis mellifera* and species belonging to the genus *Naja* have demonstrated anti-inflammatory, analgesic, antioxidant, and anti-aging activities, supporting their use in the development of innovative topical pharmaceutical formulations. Their mechanisms of action involve the inhibition of pro-inflammatory pathways NF-κB and MAPK, the reduction of COX-2 and iNOS enzyme expression, the decrease of pro-inflammatory cytokines (TNF-α, IL-1β, IL-6), and the protection of the extracellular matrix through metalloproteinase inhibition and stimulation of collagen and elastin synthesis. Through these effects, bee and cobra venoms help maintain skin homeostasis and reduce the inflammatory and oxidative processes associated with skin aging. This paper synthesizes recent data from the literature and highlights the relevance of these biomolecules in modern pharma dermatology.

Keywords: *Apis mellifera*, *Naja kaouthia*, *Naja atra*, melittin, anti-inflammatory, anti-aging

Introduction

Animal venoms have been used in traditional medicine for thousands of years and are currently intensively studied as sources of bioactive compounds with modern therapeutic potential [1]. Recent advances in proteomics and biotechnologies have allowed the

identification of the structure and mechanisms of action of the bioactive components in these complex secretions, highlighting relevant therapeutic targets [2]. Among these, bee venom (*Apis mellifera*) and cobra venom (*Naja kaouthia*, *Naja atra*) are of particular interest due to their high content of peptides and enzymes with various pharmacological effects, from neurotoxic actions to anti-inflammatory, analgesic, and antioxidant properties at controlled doses [2,3]. In dermatology and pharma dermatology, *Apis mellifera* is valued for its melittin and apamine, compounds involved in skin regeneration and inflammation inhibition, while *Naja venoms* provide neurotoxins and cardiotoxins with immunomodulatory and antioxidant effects [3,4]. The development of topical pharmaceutical forms that capitalize on these biomolecules represents an innovative direction, aimed at preventing chronic inflammation and skin aging, with significant potential in modern pharma dermatology.

Composition and Bioactivity

Compositional analysis of the venoms of *Apis mellifera* and some species of the genus *Naja*. reveals the presence of major peptides and enzymes responsible for multiple pharmacological effects: anti-inflammatory, antioxidant, analgesic, and antimicrobial, summarized in **Table 1** [2,3].

Table 1. Main bioactive components of animal venoms and their pharmacological actions.

Component	Source	Main pharmacological actions
Melittin	<i>Apis mellifera</i>	Anti-inflammatory, analgesic, antimicrobial, anti-aging (collagen stimulation)
Apamin	<i>Apis mellifera</i>	Neuroprotective, anti-inflammatory, antioxidant
Phospholipase A ₂	<i>Apis mellifera</i> , <i>Naja</i> spp.	Modulation of inflammation, membrane hydrolysis
Hyaluronidase	<i>Apis mellifera</i>	Increases tissue permeability, facilitates diffusion
Cobratoxin	<i>Naja kaouthia</i>	Anti-inflammatory, analgesic, and inhibition of cytokine release
Cardiotoxin	<i>Naja kaouthia</i>	Antioxidant, anti-aging, membrane stabilization
L-amino acid oxidase	<i>Naja</i> spp.	Antimicrobial, anti-tumoral, redox modulation

The biological activity of animal venoms goes far beyond the well-known neurotoxic and cytolytic effects, including a wide range of pharmacological properties with relevance in the control of inflammation and skin regeneration. The venoms of *Apis mellifera* and *Naja* spp. They contain peptides and enzymes with effects mediated by various cellular pathways.

The main mechanisms involved are schematically illustrated in **Figure 1**.

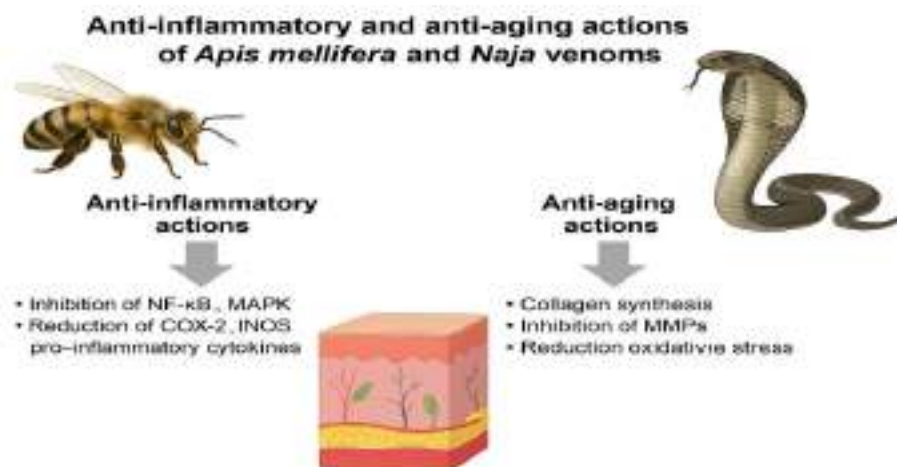


Figure 1. Schematic representation of the main anti-inflammatory and anti-aging mechanisms of *Apis mellifera* and *Naja* spp. venoms. Melittin and apamin modulate the NF-κB and MAPK signaling pathways, reducing the release of pro-inflammatory cytokines (TNF-α, IL-1β, IL-6) and oxidative stress. Cobrotoxin and cardiotoxins act synergistically by suppressing iNOS and MPO activity, preventing collagen degradation, and protecting dermal structure integrity, thereby contributing to skin homeostasis and anti-aging effects.

Bee venom contains more than 40 constituents, the most important of which are melite (~40–60% of the peptide fraction), apamine, PLA₂ and hyaluronidase, which contribute to biological effects [1–3]. Melittin modulates TLR/NF-κB pathways and reduces p38 MAPK, decreasing the synthesis of proinflammatory cytokines [1,5]. Apamine has an anti-inflammatory and antioxidant effect, correlated with the modulation of small-conductance Ca²⁺-activated K⁺ channels (SK), involved in the regulation of neuronal excitability and inflammatory response [6].

α-neurotoxins (e.g. cobrotoxin) and cardiotoxins in *Naja* spp. venoms exert anti-inflammatory effects by inhibiting IKK/IκB and blocking NF-κB p65 translocation, with decreased TNF-α and IL-1β [4,7,8].

Anti-inflammatory Mechanisms

The anti-inflammatory effects of bee venom (*Apis mellifera*) have been highlighted in numerous preclinical studies, suggesting its therapeutic potential in **chronic inflammatory conditions** such as **rheumatoid arthritis**. The administration of venom in various concentrations in murine models has led **to a reduction in paw-edema, while decreasing the arthritic index and the intensity of inflammatory pain** [9].

The **anti-inflammatory activity has also been confirmed in models of atopic dermatitis**, where the venom reduced skin inflammation and clinical manifestations of the disease, suggesting its applicability in the topical therapy of inflammatory dermatological conditions [10].

Preclinical data highlight that melittin exerts an anti-inflammatory effect by inhibiting NF-κB activation, reducing the expression of COX-2 and iNOS enzymes, and decreasing the production of the pro-inflammatory cytokines TNF-α and IL-6 [1,5]. Apamine contributes to the decrease of inflammation in skin and systemic models, acting by regulating SK channels and reducing oxidative stress [6].

In the case of venoms of the genus *Naja*, the major peptides: **cobrotoxin, cobrotoxin, and cardiotoxins**, exhibit complex anti-inflammatory effects, mediated by **modulation of the NF-κB, MAPK, and JAK/STAT signaling pathways**. Experimental studies have shown that these toxins can **reduce the levels of the proinflammatory cytokines TNF-α and IL-1β**, inhibit **the nuclear translocation of the p65 subunit** and decrease **myeloperoxidase (MPO) activity**, as well as **iNOS expression**, mechanisms that contribute to limiting inflammation [7,8].

Due to these actions, ***cobrotoxin*** stands out as a promising therapeutic candidate for the treatment of chronic inflammatory conditions, through its ability to simultaneously regulate **the immune response and the enzymatic processes** involved in the inflammatory cascade [11,12].

These molecular mechanisms support the potential of the controlled use of bee and cobra venoms in topical pharmaceutical forms with the aim of reducing skin inflammation, erythema and local discomfort.

Anti-aging Mechanism

As the largest and most exposed organ of the human body, **the skin** is permanently subjected to a wide spectrum of environmental factors, such as **temperature variations, ultraviolet radiation, cigarette smoke, ozone and various chemical pollutants**. All these factors are brought together in the modern concept of **"exposure" (exposome)**, which designates the set of external and internal influences exerted on the body from birth to the end of life – a term recently introduced in dermatological and toxicological research [13,14]. In addition to physico-chemical aggressors, **psychological stress** is an important determinant of skin balance, manifesting itself when external demands exceed the individual's adaptive capacities and generating complex **emotional, behavioral and physiological changes** [14]. Oxidative and inflammatory processes activate the secretion of degradative enzymes, such as neutrophilic elastase and metalloproteinase-8 (MMP-8), involved in the fragmentation of collagen and elastic fibers, a mechanism that contributes to the appearance of wrinkles and loss of skin elasticity [15]. Preventing these manifestations, including xerosis, diminishing firmness and skin tone, is a major challenge for modern dermatology.

Skin aging causes obvious morphological and functional changes in the epidermis, dermis and subcutaneous tissue. In the epidermis, thinning of cell layers, flattening of the dermo-epidermal junction, reduction of hydration and lipid content, associated with increased transepidermal water loss (TEWL) are observed. At the dermis level, aging is characterized by a decrease in the number and activity of fibroblasts, decreased collagen and elastin synthesis, fragmentation of supporting fibers, and reduced hyaluronic acid content, which leads to a loss of skin suppleness and strength [14,16].

Research in the field of anti-aging therapies has undergone a constant evolution. The bioactive substances in topical products help **maintain the integrity of the skin barrier** by **moisturizing and replenishing lipids**, reducing structural skin degradation [13].

Anti-aging ingredients work by **inhibiting enzymes involved in the degradation of collagen and elastin**, while formulations based on natural compounds are valued for **moisturizing and protecting dry and mature skin**, although **their efficacy in vivo** still requires further studies [14,16].

The process of skin aging is associated with oxidative stress, chronic inflammation and degradation of the extracellular matrix. Recent studies on bee venom (*Apis mellifera*) have demonstrated that **melittin** and other bioactive components can **stimulate collagen and elastin synthesis** (by increasing the expression of the *Colla1* and *Col3a1* genes) and **inhibit the degradation of the extracellular matrix**, thus helping to maintain **skin elasticity and firmness** [17].

Through these mechanisms, bee venom improves the appearance of wrinkles and is considered a valuable ingredient in products intended for mature skin. Due to its ability to influence **skin neurotransmission and relax muscles involved in facial expressions**, its effect

is often compared to that of *botulinum toxin* but achieved through a natural and non-invasive mechanism [14].

In parallel, snake venoms of the genus *Naja* have demonstrated antioxidant activity and protective effects on fibroblasts by maintaining the integrity of cell membranes and reducing oxidative stress [18]. By reducing pro-inflammatory mediators and lipid peroxidation, these venoms may provide a promising platform for topical formulations with anti-aging action."

Pharmaceutical Considerations for Topical Use

The formulation of animal venoms in topical products requires **strict control of concentration, compatibility with the physiological pH of the skin** (5.0–6.0), as well as ensuring **the physicochemical and microbiological stability** of the active ingredients [19,20]. For healthy skin, the literature recommends slightly acidified formulations (pH $\approx$ 4–6), which support barrier function and the skin microbiome [19].

O/W creams and carbomeric gels are vehicles of choice for topical applications, providing controlled **release** and **good long-term stability** [2,20–22].

Since bioactive peptides, such as **melittin**, are susceptible to hydrolytic degradation and can induce irritative reactions at high doses, their integration into **nano-vehicular systems** (e.g., **PEG-PLGA nanoparticles or carbomeric ethosome-gels**) **is pursued**, which confer **increased stability, improved local bioavailability, and reduced irritation** [23,24]. In all cases, **dermatological safety assessment** – including local tolerance, irritation and sensitisation tests – remains an essential step before clinical validation [2,3].

Although the venoms of species of the genus *Naja* (including *Naja kaouthia* and *Naja atra*) are among the most studied in terms of systemic toxicity, especially by injection or oral administration in animal models, **no studies specifically evaluating dermal toxicity or safety of topical use have been reported to date**.

Conclusions

Bioactive peptides and proteins identified in the venoms of *Apis mellifera* and *Naja spp.* It acts convergently on the main signaling pathways involved in inflammatory and oxidative processes, demonstrating significant therapeutic potential for topical pharmaceutical and dermatocosmetic applications. By inhibiting the **NF- κ B** and **MAPK** pathways, reducing **COX-2/iNOS** expression and proinflammatory cytokines (**TNF- α** , **IL-1 β** , **IL-6**), as well as protecting the extracellular matrix (inhibiting MMPs and stimulating collagen and elastin synthesis), these biomolecules contribute to maintaining skin homeostasis and reducing premature skin aging. Recent data also support the inclusion of melittin, apamine, cobratoxin, and cardiotoxins in modern controlled delivery systems, such as **nano emulsions, liposomes, ethosomes, or PEG-PLGA polymer nanoparticles**, which optimize peptide stability, local bioavailability, and skin tolerance. The integration of these bioactive compounds in **O/W creams and carbomeric gels** with physiological pH (5.0–6.0) provides a promising technological basis for the development of safe and effective pharmaceutical forms.

However, for clinical validation, it is necessary to expand research on **dose-effect correlation, local and systemic safety, long-term stability, and molecular mechanisms of action**. The results presented can constitute a solid basis for the development of **innovative therapeutic and cosmetic strategies**, based on biomolecules derived from animal venoms, with applicability in anti-inflammatory, repairing, and antiaging skin treatments.

The venoms of *Apis mellifera* and *Naja spp.* They are valuable natural sources of peptides and enzymes with biological activities relevant to dermato-pharmacology. Both *in vitro* and *in vivo* studies have demonstrated **anti-inflammatory, antioxidant, and anti-aging** properties **for bee venom** by topical application, confirming its safety and efficacy in humans and animal models. In contrast, for **cobra venoms**, existing research highlights significant **anti-inflammatory and immunomodulatory** effects in systemic administration, but **skin toxicity and safety of topical use** remain insufficiently investigated. These data support the need to expand studies towards the development of **safe and effective topical formulations** based on *Naja spp.*, with therapeutic and antiaging potential comparable to that of *Apis mellifera venom*.

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IMPACT OF ORTHODONTIC TREATMENT ON ADOLESCENTS' SELF-ESTEEM

Associate Professor, PhD Sorana Maria BUCUR¹; Associate Professor, PhD Carmen GALEA^{1*}; Lecturer, PhD Doina MOALEȘ^{1*}; Lecturer, Ph.D . Claudia NISTOR¹

¹*Department of Dentistry, Faculty of Medicine, Dimitrie Cantemir University of Târgu Mureș, 540545 Târgu Mureș, România*

Corresponding author: Carmen Gălea: unicapharm@gmail.com; Doina Moaleș: moldoina@yahoo.com

Abstract

Objective: This cross-sectional comparative study aimed to evaluate whether undergoing orthodontic treatment influences changes in self-esteem among adolescents treated at the Dimitrie Cantemir University Dental Clinic.

Materials and Methods: A total of 158 adolescents aged 12 to 17 years who attended the clinic for routine dental check-ups or orthodontic treatment were included. Participants were divided into two groups: those who had received orthodontic treatment within the last two years ($n = 64$) and those who had never received such treatment ($n = 94$). Self-esteem levels were assessed using a brief validated version of the Lawrence Self-Esteem Questionnaire (LAWSEQ). Demographic data and parental education levels were also recorded. Group differences were analyzed using t-tests and linear regression, adjusting for age, sex, and socioeconomic background.

Results: Adolescents with orthodontic treatment reported slightly higher mean self-esteem scores (14.8 ± 3.2) compared with untreated peers (14.1 ± 3.5), though the difference was not statistically significant ($p = 0.21$). Higher maternal education and female gender were both modestly associated with higher self-esteem. No significant relationship was found between the duration of orthodontic treatment and self-esteem levels.

Conclusion: Within the limits of this study, orthodontic treatment was not significantly associated with higher self-esteem among adolescents. Psychological well-being in this age group appears to depend more on family and social factors than on dental appearance alone.

Keywords: self-esteem; orthodontic treatment; adolescents; dental aesthetics; quality of life.

Introduction

Adolescence is a critical developmental period characterized by profound physical, emotional, and social changes. During this stage, self-esteem plays a central role in shaping psychological well-being, social interactions, and overall quality of life [1]. Body image and facial appearance are particularly influential factors, as adolescents become increasingly sensitive to peer perceptions and social comparison [2].

Malocclusion is a common dental condition during adolescence and has often been associated with aesthetic concerns, social discomfort, and potential psychosocial impacts. Orthodontic treatment is widely promoted not only to improve dental function and facial

aesthetics but also to enhance self-confidence and self-esteem [3,4]. However, evidence regarding the psychological benefits of orthodontic treatment remains inconsistent. While some studies suggest improvements in self-perception and social confidence, others report minimal or no measurable changes in self-esteem [3,4].

Self-esteem questionnaires are self-report tools with statements about one's worth, typically using Likert scales (e.g., agree/disagree) to gauge feelings of value, competence, and self-acceptance, with common examples like the **Rosenberg Scale** (10 items, overall self-worth) or the **Coopersmith Inventory** (used for children), helping identify growth areas for better mental health [5,6].

Self-esteem questionnaires are designed to capture how people view and value themselves. At their core, these tools aim to measure global self-esteem—a person's overall sense of self-worth—while some also look more closely at specific dimensions, such as self-competence (how capable someone feels) and self-liking (how satisfied they are with themselves) [3-6].

Typically, these questionnaires take the form of short statements like *"I feel that I have some good qualities."* Respondents indicate their level of agreement or disagreement using a rating scale, typically ranging from four to five points. Once completed, the responses are scored by adding up the item values. Negatively worded statements are usually reverse scored so that the final total reflects a consistent direction, with higher scores generally indicating higher self-esteem [5,6].

Because of their simplicity and reliability, self-esteem questionnaires are widely used in psychology, research, education, and therapeutic settings. Clinicians and researchers rely on them to assess a person's self-view, track changes over time, and better understand links between self-esteem and mental health [3-6].

Several well-known questionnaires demonstrate how these tools are applied in practice. The Rosenberg Self-Esteem Scale (RSES) is the most widely used, consisting of 10 items that measure overall positive or negative attitudes toward the self. It is easy to score, producing a total score (commonly ranging from 0 to 30) that can be interpreted as low, normal, or high self-esteem [5].

For younger populations, the Adolescent Self-Esteem Questionnaire (ASQ) [7] offers a 13-item format tailored specifically to adolescents, while the Coopersmith Self-Esteem Inventory (CSEI) [6] is often used in educational contexts with children. In contrast to these trait-focused measures, the State Self-Esteem Scale (SSES) [7,8] assesses how a person feels about themselves in the moment, capturing temporary fluctuations rather than stable self-beliefs.

Overall, self-esteem questionnaires provide valuable insight into whether individuals feel capable, worthy, and self-accepting, or whether they struggle with doubt and self-criticism. By offering a clear snapshot of self-perception, these tools create a useful starting point for therapy, self-reflection, and personal growth [3-8].

The Lawrence Self-Esteem Questionnaire (LAWSEQ) is a widely used, 16-item tool for measuring self-esteem in school children (Key Stages 1, 2, 3) in the UK, developed by D. Lawrence, assessing a child's self-perception through simple "Yes/No/Don't Know" answers about feelings and traits, aiming to reveal discrepancies between their 'self-image' and 'ideal-self' for educational or clinical insights [9,10].

Given these conflicting findings, the present study aimed to evaluate whether adolescents who have undergone orthodontic treatment exhibit different self-esteem levels compared with peers who have not received such treatment. Additionally, the study explored the influence of demographic and family-related factors on adolescent self-esteem.

Materials and Methods

Study Design and Sample

This cross-sectional comparative study was conducted at the Dimitrie Cantemir University Dental Clinic. A total of 158 adolescents aged between 12 and 17 years were recruited during routine dental visits or orthodontic follow-up appointments.

Participants were divided into two groups:

- **Orthodontic treatment group** (n = 64): adolescents who had received orthodontic treatment within the previous two years.
- **Control group** (n = 94): adolescents with no history of orthodontic treatment.

Exclusion criteria included the presence of craniofacial syndromes, severe systemic or psychiatric disorders, and incomplete questionnaire data.

Data Collection

Self-esteem was assessed using a brief, validated version of the *Lawrence Self-Esteem Questionnaire (LAWSEQ)* (Figure 1), which is commonly used in adolescent populations. Higher scores indicate higher levels of self-esteem. Additional data collected included age, sex, and parental education level, the latter being used as a proxy indicator of socioeconomic background.

Statistical Analysis

Descriptive statistics were calculated for all variables. Differences in self-esteem scores between groups were analyzed using independent-samples t-tests. Linear regression analysis was performed to assess the association between orthodontic treatment and self-esteem while adjusting for age, sex, and parental education level. Statistical significance was set at $p < 0.05$.

	Yes	No	Don't know
1. Do you think that your parents usually like to hear about your ideas?			
2. Do you often feel lonely at school?			
3. Do other children often break friends or fall out with you?			
4. Do you like team games?			
5. Do you think that other children often say nasty things about you?			
6. When you have to say things in front of teachers, do you usually feel shy?			
7. Do you like writing stories or doing creative writing?			
8. Do you often feel sad because you have nobody to play with at school?			
9. Are you good at mathematics?			
10. Are there lots of things about yourself you would like to change?			
11. When you have to say things in front of other children, do you usually feel foolish?			
12. Do you find it difficult to do things like woodwork or knitting?			
13. When you want to tell a teacher something do you usually feel foolish?			
14. Do you often have to find new friends because your old friends are playing with somebody else?			
15. Do you usually feel foolish when you talk to your parents?			
16. Do other people often think that you tell lies?			
 KEY:			
Score +2 for all numbers answering 'no' except for question 1. Score +2 for question 1 answering 'yes'. 4, 7, 9, 12 do not count.			
Score +1 for all answers 'don't know'.			
© 1996 Denis Lawrence			

Lawrence Self-Esteem Questionnaire (LAWSEQ)

Results

Participant Characteristics

The mean age of participants was comparable between the orthodontic treatment group and the control group. Female participants constituted a slightly higher proportion of the sample. No significant differences were observed between groups regarding age or parental education level.

Figure 1 illustrates the comparison of mean self-esteem scores between adolescents who had undergone orthodontic treatment and those who had never received orthodontic treatment. Adolescents in the orthodontic treatment group demonstrated a slightly higher mean LAWSEQ self-esteem score (14.8 ± 3.2) compared with the control group (14.1 ± 3.5). However, the substantial overlap of error bars indicates considerable variability within both groups, and the observed difference was not statistically significant ($p = 0.21$). These findings suggest that orthodontic treatment status alone does not have a strong influence on self-esteem levels in this adolescent population.

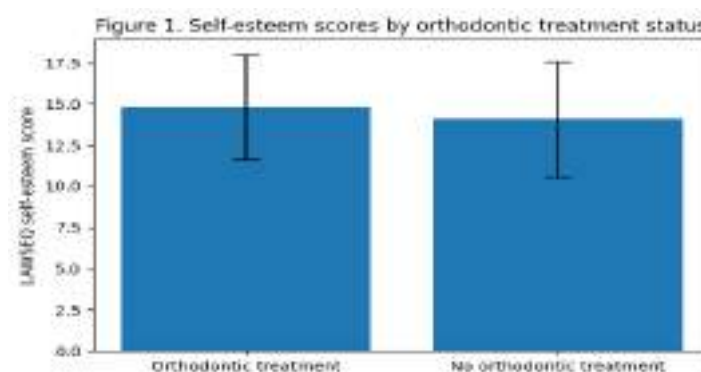


Figure 1. Self-esteem scores by orthodontic treatment status, *error bars representing standard deviation*

Self-Esteem Outcomes

Adolescents who had undergone orthodontic treatment reported a slightly higher mean self-esteem score (14.8 ± 3.2) compared with untreated peers (14.1 ± 3.5). However, this difference did not reach statistical significance ($p = 0.21$).

Regression analysis confirmed that orthodontic treatment status was not a significant predictor of self-esteem after adjusting for potential confounders. No significant association was found between the duration of orthodontic treatment and self-esteem levels.

Table 1. Predictors of adolescent self-esteem (multivariate regression)

Predictor	β	95% CI
Orthodontic treatment	0.25	-0.35 to 0.85
Female gender	0.68	0.12 to 1.24
Maternal education	0.74	0.21 to 1.27
Age	0.05	-0.18 to 0.28

Female gender and higher maternal education were positively associated with self-esteem, while orthodontic treatment status and age were not significant predictors.

Influence of Demographic Factors

Higher maternal education was modestly associated with higher self-esteem scores. The female gender was also associated with slightly higher self-esteem. Age and paternal education level showed no significant association with self-esteem outcomes.



Figure 2. Distribution of self-esteem scores by maternal education level

Figure 2 demonstrates the distribution of mean self-esteem scores according to maternal education level. Adolescents whose mothers had primary education reported the lowest mean LAWSEQ scores (13.6), while higher scores were observed among those whose mothers had secondary education (14.4). The highest self-esteem scores were recorded in adolescents whose mothers had university-level education (15.3). This progressive increase indicates a modest but consistent positive association between maternal educational attainment and adolescent self-esteem. These findings suggest that family-related and socioeconomic factors may exert a stronger influence on self-esteem during adolescence than orthodontic treatment status alone.

Discussion

The present study investigated the relationship between orthodontic treatment and self-esteem among adolescents and found that orthodontic treatment was not significantly associated with higher self-esteem levels [11]. Although adolescents who had undergone orthodontic treatment reported marginally higher LAWSEQ scores than untreated peers, the difference was small and did not reach statistical significance. These findings reinforce the concept that self-esteem during adolescence is a complex, multifactorial construct that cannot be explained solely by improvements in dental aesthetics [1-3].

One possible explanation for the limited psychological impact of orthodontic treatment is adolescents' rapid adaptation to changes in physical appearance [12]. While orthodontic appliances may initially influence self-consciousness, either positively or negatively, this effect may diminish over time as adolescents normalize their appearance within their peer group [12,13]. Furthermore, orthodontic treatment itself can sometimes introduce temporary discomfort, aesthetic concerns, or social attention, potentially counterbalancing any positive effects on self-esteem.

The absence of a significant association between treatment duration and self-esteem further supports the notion that prolonged orthodontic intervention does not necessarily enhance psychological well-being [13]. This finding challenges the common assumption that longer or more complex orthodontic treatment automatically leads to greater psychosocial benefits

[14,15]. Instead, it suggests that self-esteem is more strongly shaped by stable personal and environmental factors than by treatment-related variables [16].

In contrast, the modest but consistent association between higher maternal education and increased self-esteem highlights the importance of family and socioeconomic context in adolescent psychological development. Maternal education may reflect broader aspects of family support, communication style, emotional availability, and access to resources, all of which can positively influence adolescents' self-perception and coping mechanisms [17]. This observation aligns with previous research emphasizing the protective role of supportive family environments in fostering healthy self-esteem.

Gender differences observed in the present study, with female participants showing slightly higher self-esteem scores, may reflect differences in emotional awareness, social expression, or response styles to self-report questionnaires. However, given the modest magnitude of this association, gender should be interpreted as a contributory rather than a determining factor [18].

From a clinical perspective, these findings have important implications. Orthodontists should be cautious when framing orthodontic treatment as a means of improving self-esteem. While treatment offers clear functional and aesthetic benefits, expectations regarding psychological outcomes should be realistic and individualized. A holistic approach that considers emotional well-being, family dynamics, and social context may be more effective in supporting adolescent patients than focusing solely on dental appearance.

Several limitations must be acknowledged. The cross-sectional design prevents causal inference, and self-esteem was measured at a single point in time. Baseline self-esteem before orthodontic treatment was not available, limiting the ability to assess intra-individual changes. Additionally, the use of a brief self-report questionnaire may not capture all dimensions of adolescent self-esteem. Future longitudinal studies incorporating multiple psychological measures and pre-treatment assessments are needed to clarify the temporal relationship between orthodontic treatment and self-esteem.

Conclusions

Within the limitations of this cross-sectional study, orthodontic treatment was not significantly associated with higher self-esteem among adolescents. Psychological well-being in this age group appears to be influenced more strongly by family, social, and demographic factors than by dental appearance alone. While orthodontic treatment offers important functional and aesthetic benefits, its impact on self-esteem should be considered modest and individualized.

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GRAPE POMACE VALORIZATION: UNLOCKING ITS POTENTIAL FOR SUSTAINABLE AND INNOVATIVE

University Teaching Assistant, Ph.D. Student Irinel LUNGU¹; Associate Professor, PhD Ramona Diana FEIER²; Ph.D. Student Monica DINU¹; Professor, Ph.D. Olimpia DUMITRIU BUZIA¹; Ph.D. Student Cristina BAZBANELA¹; Professor, PhD Elena Lacramioara LISA¹; University Teaching Assistant; PhD Student Dorin Ioan COCOȘ³

¹Centre in the Medical-Pharmaceutical Field, Faculty of Medicine and Pharmacy, “Dunarea de Jos” University of Galati, 800008 Galati, Romania;

²Department of Dentistry, Faculty of Medicine, Dimitrie Cantemir University of Târgu Mureș, 540545 Târgu Mureș, România;

³Faculty of Dental Medicine, “Dunărea de Jos” University, 800008 Galați, Romania
Corresponding author: Ramona Diana FEIER: dr.ramonafeier@yahoo.ro

Abstract

Grape pomace, the main by-product of winemaking, represents a rich source of bioactive compounds with significant potential for pharmaceutical applications. This review highlights the strategies for valorising grape pomace as a sustainable ingredient in developing innovative pharmaceutical dosage forms. Its composition — dominated by polyphenols, flavonoids, anthocyanins, and dietary fibers — confers antioxidant, anti-inflammatory, antimicrobial, and wound-healing properties. Experimental research demonstrates that grape pomace extracts can modulate oxidative stress, inhibit bacterial growth, and promote tissue regeneration, supporting their inclusion in topical, oral, and transdermal formulations. Encapsulation techniques using liposomes, hydrogels, and polymeric nanoparticles have improved compound stability and bioavailability, enabled controlled release and enhanced therapeutic efficacy. The integration of grape pomace into pharmaceutical systems aligns with the principles of circular bioeconomy, transforming agro-industrial waste into high-value therapeutic resources. Despite promising data, challenges remain in standardizing extraction methods, ensuring reproducible phytochemical profiles, and evaluating long-term safety. The sustainable use of grape pomace offers an innovative approach to developing eco-friendly pharmaceutical products that combine efficacy, biocompatibility, and environmental responsibility.

Keywords: grape pomace, valorization, polyphenols, pharmaceutical formulations, sustainability, circular bioeconomy

1. Introduction

In recent decades, sustainability has become a fundamental principle guiding scientific research and the development of industries with environmental impacts, including the pharmaceutical industry. In this context, the identification and valorization of renewable resources and agro-industrial by-products is gaining strategic importance. Grape pomace, an organic residue produced in significant quantities by the winemaking process, has increasingly

come to the attention of the scientific community due to its complex phytochemical profile and therapeutic potential [1].

Its composition includes a wide range of bioactive compounds with proven biological activity: polyphenols, flavonoids, condensed tannins, anthocyanins, phenolic acids, and dietary fibres. These compounds have demonstrated multiple pharmacological properties in preclinical studies, such as antioxidant, anti-inflammatory, antimicrobial, and cardioprotective effects [2], [3]. For this reason, pomace is no longer viewed as just an agro-industrial waste, but as a valuable resource in the development of modern, efficient, and environmentally sustainable pharmaceutical products.

At the same time, the valorisation of grape pomace aligns with the principles of the circular economy, promoting the intelligent reuse of industrial by-products and reducing the impact on the environment. By integrating active compounds extracted from grape pomace into innovative pharmaceutical forms – such as nanoparticles, oral films, or transdermal systems – products with increased therapeutic efficiency and a reduced ecological footprint can be obtained. The present work aims to explore the potential of grape pomace in the development of innovative, sustainable, and clinically relevant pharmaceutical solutions.

2. Chemical Composition and Biological Activity

Grape marc contains a significant variety of active phytochemical compounds with documented therapeutic roles. Among the main constituents are polyphenols (especially resveratrol, gallic acid, and quercetin), as well as anthocyanins and condensed tannins. These compounds exhibit multiple biological activities, notable for their strong antioxidant capacity, as well as anti-inflammatory, antimicrobial, antiproliferative, and vasoprotective effects [4].

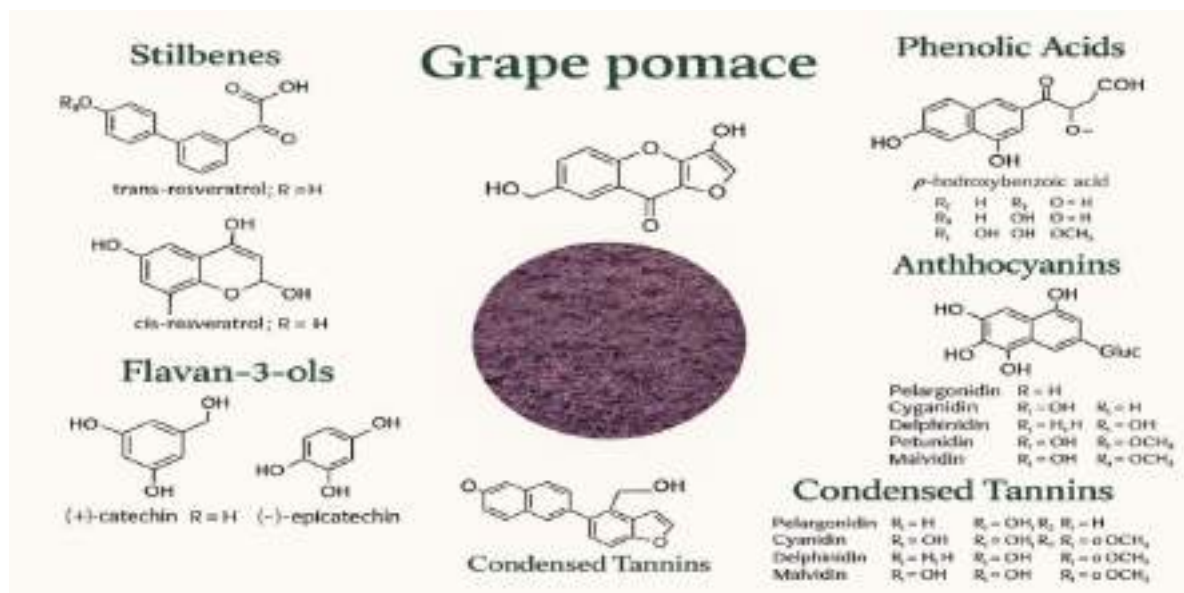


Figure 1. Main phenolic compounds found in grape pomace. Source: Adapted from literature data on grape pomace phenolic composition.

Figure 1. Schematic representation of the major phenolic compound classes presents in grape pomace, highlighting stilbenes (e.g., resveratrol), flavan-3-ols (catechins), phenolic acids,

anthocyanins, and condensed tannins, which collectively contribute to the antioxidant and bioactive potential of grape by-products.

Resveratrol, for example, is well known for its role in cardiovascular protection, reducing oxidative stress and modulating the inflammatory response, while gallic acid has antimicrobial and neuroprotective effects. Quercetin is a flavonoid with antiviral and anti-inflammatory potential, involved in reducing pro-inflammatory cytokines. Anthocyanins contribute to endothelial protection and have been associated with beneficial effects on visual and brain health.

Laboratory studies have shown that polyphenolic extracts from grape pomace have a capacity to neutralize reactive oxygen species comparable to that of established antioxidants such as vitamin C or E [3]. These extracts have also demonstrated the ability to inhibit bacterial proliferation (including resistant strains), as well as anti-inflammatory properties in in vitro and in vivo models.

The biochemical profile of pomace may vary depending on the grape variety, processing conditions, and extraction method, but the therapeutic potential of these compounds remains consistently promising, justifying further research for their application in advanced pharmaceutical formulations.

3. Extraction Methods

The choice of extraction method is a critical element in the pharmaceutical valorization process of grape pomace, directly influencing the yield, purity, stability, and bioavailability of the extracted bioactive compounds. Beyond technological efficiency, the selection of the method must consider compatibility with therapeutic purposes, compliance with safety regulations, and sustainability of the process from an industrial and ecological perspective.

Soxhlet extraction, although widely used in the past, presents notable disadvantages: long processing time, high consumption of solvents (often toxic), and increased risk of thermal degradation of sensitive compounds. In this context, modern extraction technologies have gained considerable interest, especially those that optimize operational parameters and reduce environmental impact [5].



Figure 2. Extraction, isolation and characterization of bioactive compounds from Plants
Source: Adapted from Sasidharan et al. [6].

Figure 2. Schematic overview of the sequential stages involved in the discovery of plant-derived bioactive compounds, including plant collection, extraction, isolation and purification, bioassays, structural characterization, and lead optimization. The image illustrates the

sequential process involved in the extraction, isolation, and characterization of bioactive compounds from plant sources. The workflow begins with plant collection, where selected plant materials are harvested under controlled conditions to ensure botanical authenticity and quality.

In the extraction stage, bioactive compounds are released from the plant matrix using appropriate extraction techniques, such as solvent-based extraction or assisted methods. The resulting crude extracts are then subjected to isolation and purification, which involve concentration and separation procedures including rotary evaporation, column chromatography, and preparative high-performance liquid chromatography (HPLC), enabling the obtainment of individual or enriched fractions. Subsequently, the isolated fractions undergo bioassays to evaluate their biological activities, such as antioxidant, antimicrobial, or anti-inflammatory effects, allowing the identification of compounds with significant bioactivity. The biologically active compounds are then subjected to structural characterization using advanced analytical and spectroscopic techniques, including nuclear magnetic resonance (NMR), mass spectrometry (MS), and infrared spectroscopy (FTIR), to elucidate their chemical structures. The final stage, lead optimization, focuses on improving the biological efficacy, stability, and safety of the identified lead compounds through further analysis or structural modification, supporting their potential development for pharmaceutical or nutraceutical applications.

3.1 Green Solvent Extraction

This method uses biodegradable and non-toxic solvents – in particular ethanol, acidified water or hydroalcoholic mixtures – to extract phenolic compounds from the lignocellulosic matrix of the pomace. Ethanol, for example, is approved for pharmaceutical and food use and offers an ideal compromise between polarity, safety, and extraction efficiency.

The performance of the method can be optimized by adjusting parameters such as temperature (generally 40–60°C), pH, and contact time, which results in a selective extraction of polyphenols and a significant reduction of residual contaminants. This method is considered scalable and economically viable in an industrial context.

3.2 Microwave - Assisted Microextraction Extraction (MFA)

MAE represents one of the most advanced extraction methods, based on the application of high-frequency electromagnetic radiation (typically 2.45 GHz), which rapidly heats the liquid phase and induces the degradation of plant cell walls.

This method allows for rapid extraction of polyphenolic compounds, even in aqueous media, reducing processing time from hours to minutes. In addition, MAE minimizes thermal degradation, making it ideal for sensitive compounds such as anthocyanins, catechins, or flavanols. Recent studies have reported an increase of up to 30–40% in polyphenol yield compared to conventional extraction [5].

3.3 Enzyme - Assisted Extraction Extraction (EAE)

EAE involves the use of hydrolytic enzymes – such as pectinase, cellulase or hemicellulose – to degrade the structural components of the plant cell wall, facilitating the release of soluble compounds into the liquid phase.

This method is gentle, non-invasive and compatible with pharmaceutical purity standards. The major advantage is the avoidance of high temperatures and organic solvents, which makes EAE a safe and scalable extraction technology, particularly suitable for obtaining standardized extracts for topical, oral or injectable applications.

3.4 Performance and Stability Considerations

Extraction efficiency is often assessed by quantifying total polyphenols (e.g. expressed in mg GAE/g) and by antioxidant activity assays (e.g. DPPH, ABTS, FRAP). Yields vary depending on the processing matrix, extraction conditions and type of solvent used. Modern methods such as MAE and EAE have demonstrated not only a significant increase in extraction yield, but also a superior preservation of bioactive properties, by reducing oxidation and polymerization of phenols. Thus, they are increasingly integrated into green pharmaceutical formulation strategies.

4. Innovative Pharmaceutical Applications

The integration of bioactive compounds from grape pomace into modern pharmaceutical forms represents a promising direction for the development of effective, safe and sustainable therapies. Due to the high content of polyphenols with demonstrated biological activity, pomace offers multiple opportunities for formulation into advanced delivery systems of active substances, adapted to different routes of administration and therapeutic conditions.

4.1 Nanoparticles Polymer

Nanotechnology allows the incorporation of grape pomace extracts into biocompatible polymeric particles, which can ensure the controlled and targeted release of active compounds in the body. These nanoparticles improve the bioavailability and stability of substances sensitive to oxidation or enzymatic degradation. Furthermore, their small size allows for efficient penetration at the cellular level and the possibility of oral, intravenous or topical administration [2].

4.2 Oral Mucoadhesive Films

Thin, biodegradable oral films impregnated with polyphenolic extracts represent a non-invasive alternative to tablets and capsules. They allow rapid absorption through the buccal mucosa, avoiding the first-pass effect in the liver and thus increasing the therapeutic efficiency of the active substances. Grape pomace-based formulations have shown promise in the delivery of antioxidant and anti-inflammatory agents in oral and systemic treatments [4].

4.3 Transdermal Hydrogels

Hydrogels represent an effective vehicle for the topical administration of grape pomace compounds, especially in inflammatory skin conditions. The viscoelastic properties and water retention capacity of these systems favor a slow and constant release of the active ingredients, ensuring a localized and prolonged action. Hydrogels enriched with grape pomace extract have

demonstrated anti-inflammatory activity and healing potential in dermatological and rheumatological applications [1].

These applications highlight the significant potential of pomace as an active excipient or main ingredient in the formulation of modern pharmaceutical products, contributing both to therapeutic efficiency and to reducing the environmental impact of the pharmaceutical industry.

5. Ecological and Economic Aspects

The recovery of grape pomace aligns with current trends in industrial sustainability, offering an effective solution to reduce the amount of agri-food waste generated annually by the wine industry. The transition from a linear consumption model to a circular economy involves transforming these by-products into valuable resources, capable of generating added value in sectors such as pharmaceuticals and biotechnology [3].

The integration of grape pomace extracts into the pharmaceutical development process contributes to lower production costs by using a cheap and abundant raw material. Furthermore, the use of environmentally friendly extraction methods, such as those based on green solvents or enzymes, considerably reduces energy consumption and pollutant emissions, strengthening the ecological profile of the resulting products [5].

The valorisation of this residue also contributes to increasing the competitiveness of producers in the pharmaceutical and agri-food sectors, facilitating access to new markets interested in green products, certified in terms of sustainability. In addition, the implementation of such solutions favours technological innovation, investments in the bioeconomy and regional development in wine-growing areas, transforming waste into a vector of economic progress.

Conclusions

Grape pomace is emerging as a valuable agro-industrial resource, capable of significantly contributing to the development of modern, sustainable, and efficient pharmaceutical forms. Its rich phytochemical profile, characterized by a high concentration of bioactive compounds, supports its use in diverse therapeutic applications, from topical treatments to oral and systemic administration.

The integration of pomace into innovative pharmaceutical products – such as nanoparticles, oral films, or hydrogels – not only improves the therapeutic efficacy and bioavailability of active ingredients but also offers a viable alternative to synthetic raw materials, contributing to reducing the ecological footprint of the pharmaceutical industry. In addition, its use supports the principles of the circular economy, valorizing agricultural waste into a high-value-added product.

To ensure the transfer of this technology to clinical and industrial scale, further investigations are needed, targeting extract standardization, toxicological evaluation, and demonstration of efficacy in controlled clinical trials. In this regard, grape marc offers a promising direction for sustainable pharmacological research in the next decade.

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MODERN APPROACHES TO THE EXPLOITATION OF ANIMAL VENOMS AS SOURCES OF BIOACTIVE INGREDIENTS WITH THERAPEUTIC AND COSMETIC POTENTIAL

**Ph.D. Student Monica DINU¹; Associate Professor, University Teaching Assistant;
Ph.D. Student Irinel LUNGU¹; Lecturer, Ph.D. Anna BUSUIOC²**

¹Centre in the Medical-Pharmaceutical Field, Faculty of Medicine and Pharmacy, "Dunarea de Jos" University of Galati, 800008 Galati, RO;

²"Dunarea de Jos" University of Galati, Faculty of Science and Environment, Department of Chemistry, Physics and Environment, Domneasca Street 111, 800201, Galati, Romania

Corresponding author- Irinel LUNGU: lun_iri@yahoo.com

Abstract

Animal venoms represent a complex mixture of bioactive peptides, enzymes, and low-molecular-weight compounds with remarkable pharmacological potential. This review summarizes modern approaches to the extraction, characterization, and application of animal venoms as innovative sources of therapeutic and cosmetic agents. Advances in proteomics, genomics, and molecular modelling have enabled the identification of numerous venom-derived peptides with analgesic, anti-inflammatory, antimicrobial, and anti-aging properties. Bee, snake, scorpion, and cone snail venoms are among the most studied, offering compounds capable of modulating ion channels, inhibiting inflammatory mediators, and promoting cellular regeneration. In cosmetics, low-dose formulations of these bioactive molecules have shown efficacy in reducing wrinkles, improving skin elasticity, and stimulating collagen synthesis. Nanotechnology and peptide engineering have further optimized delivery systems, enhancing stability and minimizing toxicity. Despite their potential, challenges persist in ensuring safety, standardization, and ethical sourcing. Ongoing research focuses on the biotechnological production of venom peptides through recombinant systems to reduce ecological impact and ensure reproducibility. Overall, animal venoms provide a unique and underexploited resource for developing next-generation pharmaceuticals and cosmeceuticals with targeted and sustainable bioactivity.

Keywords: animal venoms, bioactive peptides, therapeutic potential, cosmetic applications, peptide engineering, nanotechnology

Introduction

Animal venoms are highly sophisticated biochemical systems made up of a complex variety of bioactive molecules - peptides, enzymes, proteins and non-protein compounds - that have evolved over time as effective mechanisms for prey, defense or immobilization of prey. Although for a long time these secretions have been perceived exclusively in terms of their toxic and lethal effects, recent research has highlighted their considerable potential as sources of substances with selective pharmacological action and high potency [1,2].

Venom-derived compounds are distinguished by exceptional molecular specificity and increased affinity for precise biological targets, properties that make them valuable candidates for the development of new therapeutic agents [3]. A notorious example of the clinical application of these molecules is captopril—angiotensin-converting enzyme (ACE) inhibitor—inspired by the bradykinin peptide isolated from the venom of the viper *Bothrops jararaca*, which revolutionized the treatment of hypertension [4,5].

The renewed interest in the study of animal venoms is supported by major developments in the field of "omics" sciences (proteomics, transcriptomics, metabolomics), the improvement of peptide synthesis methods and the development of structural biology. These technological advances have enabled the isolation, characterization and controlled modification of natural toxins, providing a solid basis for the design of bioactive compounds with an optimized therapeutic profile [6,7].

The impressive diversity of venomous species, including snakes, scorpions, spiders, conical snails, wasps, bees and even jellyfish, considerably expands the spectrum of potential molecules with biomedical applicability [1,8].

This biological variety transforms venoms into a veritable "natural library" of compounds, whose resources are just beginning to be explored to obtain medicines and products with high therapeutic and cosmetic value.

History

The interest in venomous animals has been attested since antiquity: Aristotle systematically describes species and bites in the *Historia Animalium* (4th century î.Hr.), and Greco-Roman traditions record both toxic effects and early attempts at medical use (theiac with snake venom was used until the eighteenth century) [9]. In the early modern era, Francesco Redi demonstrates that toxicity is due to venom injected through the teeth, (1664), a founding moment of toxicology. A century later, Felice Fontana identifies venom glands and shows that the effects are systemically mediated, through the blood, not through the stomach (18th century).

The end of the nineteenth century marked the transition to specific interventions: Albert Calmette introduced anti-venom serotherapy (1896), establishing the paradigm of antitoxins [10]. The twentieth century brings the biochemical phase: enzymatic activities in the venom are reported as early as 1932 (phosphodiesterase), followed by the isolation of proteases (1959) and the classic study of α -bungarotoxin (1963), which becomes a selective marker for nicotinic receptors [11-13]. In parallel, empirical uses (analgesics, antiasthmatics) and topical venom products (ointments/creams) remain present, but with limited efficacy at very low concentrations. In recent decades, with proteomics and structural biology, interest has exploded: >1000 articles on venoms are published annually (half $\approx$ half on snakes), and venoms are gradually moving from "toxins" to **libraries of probe molecules and therapeutic prototypes**, connecting natural history with precision medicine [9].

The evolution of animal venom studies reflects an impressive transition from empirical observations in antiquity to the application of omics technologies and synthetic biology today. Table 1 presents a chronological synthesis of the main stages of research, the technologies used, and the applications that marked the development of modern toxicology.

Table 1. The main research milestones, technologies, and representative applications that shaped the development of modern toxinology.

Research stage/period	Scientific focus	Technological advances	Representative outcomes/examples	Current relevance
Antiquity – 18th century	Empirical use of venoms for healing and antidotes	Descriptive observations (Aristotle, Nicander, Redi, Fontana)	Discovery of venom glands and early antidote formulations	Historical foundation of toxinology
19th – mid-20th century	Experimental toxicology and serum therapy	Immunization and extraction techniques	First antivenoms (Calmette, 1896); identification of toxic enzymes	Start of therapeutic toxicology
1950–1980	Biochemical isolation of active compounds	Chromatography, electrophoresis	Isolation of α -bungarotoxin, phospholipases, and proteases	Functional characterization of toxins
1980–2000	Pharmacological exploration of peptides	Molecular biology, protein purification	Development of venom-derived drugs (Captopril, Eptifibatide, Tirofiban)	Entry of venom peptides into clinical use
2000–2010	“Omics” revolution in venom research	Proteomics, transcriptomics, mass spectrometry	Venomic profiling and discovery of novel peptides (conotoxins, melittin analogs)	Expansion of bioactive venom databases
2010–present	Synthetic biology and peptide engineering	Recombinant expression, cyclization, cryo-EM, NMR	Stable analogs (Dalazatide, Hi1a, melittin nanocarriers)	Emergence of next-generation biopharmaceuticals
Future directions	Translational and cosmetic toxicology	Integration of omics, AI-based design, and nanocarriers	Personalized antivenoms and bioactive skincare formulations	Innovative therapeutic and cosmetic development

Chemical Composition of Animal Venoms

Animal venoms are highly complex biochemical mixtures, consisting mainly of peptides, proteins and enzymes with diverse biological activities. These specialized secretions have evolved to immobilize prey or defend themselves from predators, acting on various molecular targets, such as ion channels, cell receptors, or key metabolism enzymes [9].

From the point of view of origin, they can be classified into venoms of snakes, scorpions, spiders, conical snails, bees, etc., and functionally, into neurotoxic, hemotoxic, cytotoxic or myotoxic venoms [14]. As a rule, venoms are concentrated aqueous solutions, which can contain several hundred different components, mainly protein and peptide toxins, along with non-protein molecules with a transport or stabilizing role. Through their concerted action, these toxins can cause severe disruptions of the nervous, cardiovascular and muscular systems, explaining the increased lethality of some venomous species. In cases of poisoning, treatment is based on specific antisera obtained against the whole venom [15].

Major Components of Venoms

Enzymes – especially hydrolases (phospholipase A₂, proteases, hyaluronidases, acetylcholinesterases) and, more rarely, oxidases (especially L-amino acid oxidase), predominant in snake venoms.

Non-enzymatic proteins – such as three-finger toxins, disintegrins, proteinase inhibitors and nerve growth factors, which interact with specific cellular targets [16];

Bioactive peptides – essential components in the venoms of *Elapidae*, spider, scorpion or conical snail, involved in blocking ion channels, modulating the immune response or antimicrobial activity [17].

The **neurotoxins** in the venoms of scorpions and spiders act predominantly on the voltage-dependent ion channels, while those in the venoms of *the Elapids* (snakes of the genera *Naja*, *Bungarus*, *Dendroaspis*) target ligand-dependent channels, especially the nicotinic acetylcholine receptors. Similarly, the conotoxins of *Conus* snails exhibit high specificity for both calcium and sodium channels and cholinergic receptors [9].

Marine venoms, derived from jellyfish and sea anemones, include cytolytic, hemolytic and neurotoxic proteins and peptides, which offer significant potential for the development of innovative therapeutic agents [18].

Although these marine sources are still insufficiently explored compared to land-based venoms, they constitute an emerging frontier in the discovery of drugs based on bioactive toxins [19].

The structural and functional diversity transforms animal venoms into valuable sources for the discovery of new pharmacological agents and for the development of innovative drugs for neurological, cardiovascular, inflammatory or infectious diseases.

Modern Characterization and Molecular Perspectives

The translation of venom components into therapeutic candidates has been accelerated by recent technological advances in areas such as **transcriptomics, proteomics, structural biology, and computational modeling**. These tools transformed the study of venoms from a descriptive science into a mechanistic and predictive approach.

Next-generation **sequencing technologies (NGS)** have enabled the realization of venom gland transcriptomes from numerous species, identifying not only major families of toxins (SVMP, SVSP, PLA₂, CTL), but also new, low-abundance proteins potentially relevant for **antivenom development and drug discovery** [21,22]. Proteomics **based on LC-MS/MS** complement this data, providing precise information on the molecular weight, sequence and post-translational changes of toxins, allowing a detailed functional characterization of venom [20].

In parallel, **bioinformatics and molecular modeling** have become key tools for optimizing the process of discovering venom-derived drugs. Techniques such as **molecular docking, molecular dynamics (MD) and QSAR analyses** allow prediction of binding affinities and pharmacophores, significantly reducing experimental time and costs [23,24].

By integrating these advanced methodologies, venom research has entered a new stage, in which **experimental data, in silico modeling and molecular engineering converge** towards the rational discovery of bioactive molecules with high therapeutic potential.

In recent decades, advances in molecular biology and "omics" technologies have led to a much deeper understanding of the composition of animal venoms. This is how the term

"venomics" appeared, defined as a branch of proteomics that deals with the identification and integral characterization of the proteins and peptides that make up the veins. The application of these techniques has allowed the deciphering of complete sets of toxins, even in species previously considered "minor" from a toxinological point of view [9].

A significant example is the profiling of the venom of the species *Thamnodynastes strigatus*, which highlighted new molecules of biological relevance, including a distinct type of matrix metalloproteinase, structurally different from those known in classical snake venoms [25].

Another emerging area of interest is the study of peptides capable of crossing the blood-brain barrier (BBB), thus opening new perspectives for the development of drugs for the central nervous system. For example, apamine in bee venom and its non-toxic analogues have been shown to be able to penetrate the BBB [26]. Similarly, chlorotoxin derived from scorpion venom has been used as a molecular vehicle in the detection of brain tumors — the prototype "Tumor Paint BLZ-100", a fluorescent bioconjugate with a role in the intraoperative delimitation of neoplastic tissues [9]. At the same time, recent studies show that certain proteins in snake venoms can also cross the blood-brain barrier, providing new avenues for the design of therapeutic agents with central action [27].

In addition, sequencing the genome of the king cobra (*Ophiophagus hannah*) represented an important step in understanding the genetic arsenal involved in the biosynthesis and diversification of toxins [28].

Recent advances in synthetic biology, peptide engineering, and biotechnology have revolutionized the way we investigate and harness venom-derived compounds. Recombinant expression systems – based on bacterial, yeast, insect or mammalian cells – allow the large-scale production of venom peptides with high structural fidelity and control over post-translational changes [29].

In parallel, chemical synthesis and cyclization of peptides offer the possibility of obtaining stable analogues with improved bioavailability and selectivity [30].

Structural biology techniques, such as X-ray crystallography, cryo-electron microscopy (cryo-EM) and MRI spectroscopy, provide atomic-level information on toxin–target interactions, facilitating the rational design of therapeutic analogues [31,32].

In combination with functional tests and pharmacological profiling, these methods contribute to the identification and optimization of venom-based drug candidates [33].

The integration of these advanced approaches ushered in a new era in venom research, allowing for the systematic exploration of their chemical diversity and accelerating the transformation of toxic molecules into next-generation therapeutic agents [34].

These discoveries confirm that animal venoms are no longer just the object of toxinological study, but true biotechnological platforms for the identification of new shuttle peptides, biomarkers and therapeutic prototypes with targeted action.

For a synthetic representation of the current stages involved in the process of research and valorization of animal venoms, a *general model of the biotechnological flow is presented in Figure 1, from venom extraction to the development of bioactive compounds with therapeutic and cosmetic potential.*

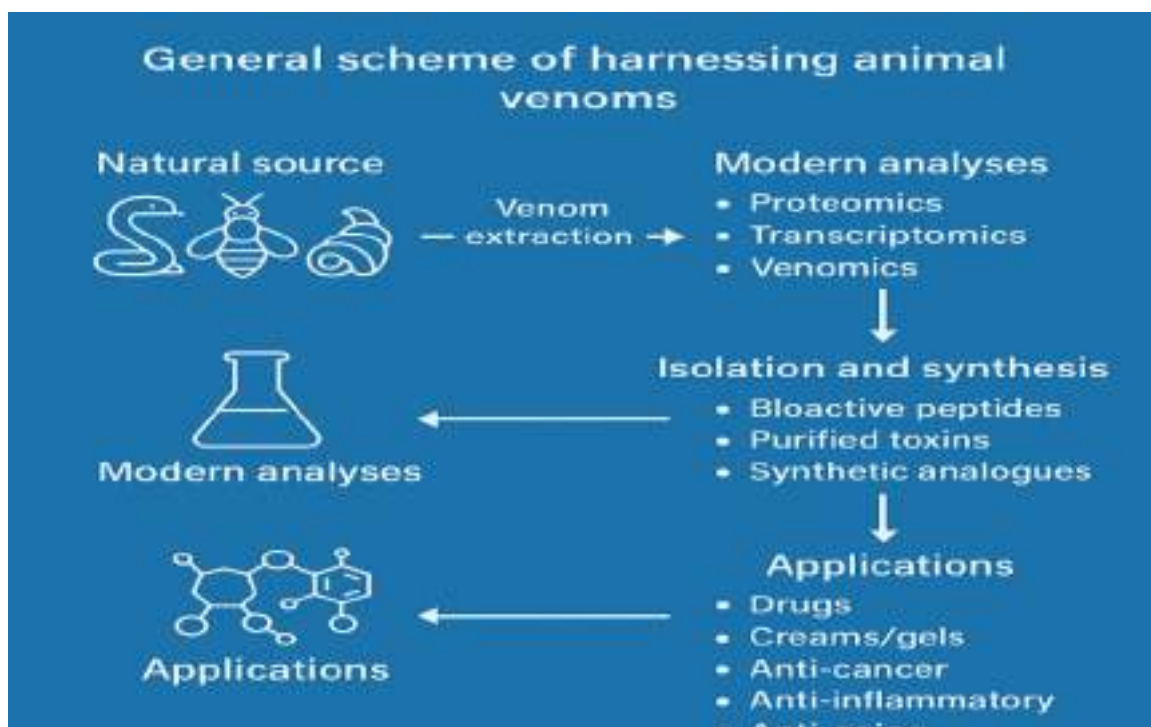


Figure 1. General scheme of modern stages in the valorization of animal venoms – from extraction to therapeutic and biotechnological applications.

The figure illustrates the general workflow involved in the modern valorization of animal venoms, highlighting the transition from natural sources to therapeutic and biotechnological applications. The process begins with the collection of venoms from animal sources such as snakes, scorpions, spiders, and insects, followed by controlled venom extraction procedures. Subsequently, the extracted venoms undergo **advanced molecular analyses**, including proteomics, transcriptomics, and venomics, which enable comprehensive characterization of venom composition at the protein, gene expression, and molecular levels. These analytical approaches facilitate the identification of biologically active compounds and molecular targets of interest. The next stage involves **isolation, purification, and synthesis**, where bioactive peptides and toxins are separated, structurally characterized, and, when necessary, reproduced or optimized through chemical synthesis or biotechnological methods to improve stability, specificity, and safety. Finally, the identified and optimized venom-derived compounds are translated into **practical applications**, including the development of pharmaceutical drugs, topical formulations such as creams and gels, as well as therapeutic agents with anticancer, anti-inflammatory, and antimicrobial properties. Overall, the figure emphasizes an integrative and interdisciplinary approach to venom research, combining natural product extraction with modern analytical techniques to support biomedical innovation.

Medically Approved

Of the drugs derived from commercialized toxins, one comes from cone snails (ziconotide), two from lizards (exenatide, lixisenatide), two from leeches (desirudine, bivalirudine) and six from snakes (captopril, enalapril, tirofiban, eptifibatide, batroxobine, cobratide) [8].

The dominance of snake venoms is explained by higher availability and early targeting of hemostasis/cardiovascular; Subsequently, "omics" techniques paved the way for poorly expressed toxins and neuronal targets [35-37].

Diagnostic Tools

Several toxins are standard reagents: Reptilase® (Reptilase time for fibrinogen/coagulation), RVV-V and RVV-X (activators of factors V and X), ecarina (ECT/ACE test for thrombin/prothrombin), as well as Botrocetin® (vWF–GPIIb interaction) and Protac® (activation of protein C), useful in the evaluation of coagulation disorders, resistance to activated protein C and anticoagulant lupus [8].

Cosmeceutical

With the deepening of knowledge of skin physiology, the boundary between cosmetics and pharmaceuticals has gradually blurred, favoring the emergence **of cosmeceuticals** - preparations that combine aesthetic effects with the action of biologically active compounds capable of modifying skin functions at the cellular level [38].

The integration of natural bioactive compounds has redefined the concept of dermatocosmetic care, orienting the industry towards formulas with anti-aging, antioxidant and regenerative effects [39]. Among the emerging sources, **animal venoms** stand out as an exceptional reservoir of bioactive molecules, still little capitalized in the cosmeceutical field. Although their use is well documented in analgesic and cardiovascular therapies, their application potential in skin health and rejuvenation remains an insufficiently explored scientific frontier [8].

Beyond Botox® (toxin isolated from the bacterium *Clostridium botulinum*), cosmetic applications inspired by venom include bee venom products to reduce wrinkles; Argiotoxin-636 (spider venom) with melanogenesis inhibitory effect (including patented applications) and synthetic tripeptide "SYN-AKE", which mimics waglerin-1 (*Tropidolaemus wagleri* venom) for local muscle relaxation and anti-wrinkle effect [40-43].

Clinical Experiences and Limitations in the Development of Venom-derived Drugs

Although many peptides and proteins derived from venoms have reached clinical stages, only a small fraction have been approved, with many discontinued due to safety, efficacy, or commercial viability concerns. Notable examples include **ximelagatran** (a mimetic derivative of cobra venom), withdrawn for hepatotoxicity, and **agkisacutacin**, a serine protease from *Deinagkistrodon acutus*, associated with severe anaphylactic reactions. Other programs, such as **pegiganan** isolated from the skin of the frog *Xenopus laevis* and the synthetic conotoxins **leconotide** and **Xen2174**, have been discontinued due to demonstrated toxicity, reduced tolerance, or lack of efficacy [45-47].

Similarly, **alfimeprase**, a recombinant fibrinolytic metalloprotease, was abandoned in phase III due to insufficient clinical outcomes [48].

The case **of lepirudine**, (marketed for the prophylaxis or treatment of thrombosis that complicates heparin-induced thrombocytopenia) withdrawn from the market in 2012, also highlights the fragility of production chains and the economic aspects that can affect the maintenance of some biological therapies [8].

These experiences underline the importance of rigorous assessment of the toxicological profile, technological sustainability and commercial feasibility from the early stages of the development of toxin-based medicines.

Challenges and Prospects in the Therapeutic Use of Venoms

Although compounds derived from venoms offer great therapeutic potential, their transposition into clinically approved pharmaceuticals remains difficult due to a set of scientific, technological, ethical and regulatory challenges.

Complexity and Variability of Venom Composition

Venoms are biochemical mixtures of exceptional complexity, containing hundreds of peptides and proteins whose expression varies significantly depending on species, age, diet, habitat or individual physiological factors [14,49].

This molecular diversity complicates the process of standardization, reproduction of experimental results and industrial scaling of bioactive compounds. In addition, the identification and isolation of minority molecules with relevant pharmacological activity remains difficult even in the context of modern proteomic analysis tools [50].

Pharmacokinetic and Immunological Limitations

Many peptides of animal origin exhibit low stability, short half-life, and limited oral bioavailability, requiring structural optimization strategies or advanced formulations to ensure effective administration. Techniques such as pegylation, cyclization or encapsulation in nanoparticles can improve stability and reduce immunogenicity, but these changes can alter pharmacodynamics and require further validations [51-53]. Immunogenicity is another major challenge: being exogenous proteins, toxins can induce hypersensitivity reactions or anaphylaxis, especially in cases of repeated administration [51,53].

Sustainability and Ethical Issues

Harvesting venoms for commercial purposes raises ecological and ethical issues, as many venomous species are rare or threatened [54]. Traditional extraction, which is difficult to standardise, poses risks to animals and can contribute to biodiversity loss. In this context, alternative methods such as recombinant production, analogue peptide synthesis, and the use of synthetic biology platforms, capable of generating functional bioactive molecules with a reduced ecological footprint, are intensively explored [55].

Regulatory and Economic Constraints

From a regulatory perspective, venom-derived compounds are at the intersection of biologics and small molecules, which complicates the approval process and imposes rigorous requirements for preclinical and clinical trials [8]. High production costs, patent difficulties, and associated financial risks often discourage industrial investment, despite the obvious scientific and medical value.

Modern Development Directions

Recent advances in artificial intelligence (AI), machine learning, and systems biology offer promising prospects for accelerating the discovery and optimization of venom-derived compounds [56]. These technologies allow rapid analysis of venous databases, prediction of biological activities, and identification of relevant therapeutic targets. In parallel, the integration of personalized medicine concepts could allow the adaptation of venom-based therapies to the genetic and physiological profile of the patient, especially in complex diseases such as cancer or autoimmune disorders [57].

Biotechnological Approaches in the Treatment of Poisoning

In parallel with the development of new therapeutic platforms, **antivenom therapy** continues to be the leading standard in the treatment of poisoning. The introduction of 'omics' technologies has also brought significant progress in this area, allowing **the transcriptomic and proteomic characterisation of veins**, the identification of geographical variations and the formulation of more specific and safer antivenoms [9].

Recent examples include the use of DNA immunization to induce antibodies capable of completely neutralizing the haemorrhagic activity of the *Bothrops asper* venom [58].

These approaches offer a **new biotechnological model for obtaining anti-tension** and the potential for their extension to other species. However, **many dangerous venoms remain insufficiently characterised**, and the lack of access to effective treatments in endemic regions underlines the continued need for innovation. In this context, the integration of "omics" methodologies in toxicology studies **represents a promising direction for the discovery of new therapeutic toxins and the improvement of antivenom therapy**.

Nanomaterials and Innovative Strategies in the Valorization of Animal Venoms

The integration of nanotechnology into animal venom research has opened up new perspectives for optimizing the pharmacological properties of bioactive toxins and peptides. Nanomaterials, such as chitosan, gold, silica, or polylactide nanoparticles, can function as carriers or adjuvants, allowing for controlled release, increased bioavailability, and reduced systemic toxicity. The encapsulation of raw venoms or purified components in biodegradable matrices is effective in stimulating the immune response (in the case of scorpion toxins) or in increasing the antigenic and prophylactic potential, providing promising alternatives to conventional adjuvants [59,60]. Also, combinations of silica nanoparticles and cobra venoms (*Walterinnesia aegyptia*) have demonstrated amplified antitumor effects, by inducing apoptosis and oxidative stress at the cellular level [61]. Peptides isolated from the venom, such as melittin from *Apis mellifera* or α -conotoxin from *Conus imperialis*, have been successfully integrated into targeted nano systems, resulting in conjugates capable of selectively directing drugs to tumor cells, with reduced adverse effects [62,63]. Similarly, gold nanoparticles conjugated to the NKCT1 toxin in *Naja kaouthia* induced programmed cell death in human leukemic lines, while chlorotoxin in the venom of the scorpion *Leiurus quinquestriatus* was used for glioma imaging and therapy, by conjugation with supermagnetic nanoparticles or quantum dots [64-67].

Conclusions

Through the complexity and uniqueness of their composition, animal venoms prove to be a veritable "living library" of active molecules, capable of inspiring the discovery of modern therapies for diseases that continue to represent major challenges in contemporary medicine. It is highlighted that animal venoms today go beyond their simple toxinological value, becoming **complex biotechnological resources** with major potential in the discovery of **bioactive peptides, diagnostic biomarkers, and molecular models for the development of targeted and innovative therapies**.

The results of the studies demonstrate the growing role of nanotechnology in converting toxic compounds into safe and effective therapeutic agents, providing an advanced platform for the development of personalized treatments and innovative medical biotechnologies.

The integration of 'omics' technologies into toxicological research redefines the way animal venoms are approached, providing a modern biotechnological framework for the development of more specific and safer antivenoms. Despite progress, many dangerous venoms remain insufficiently characterised, and limited access to effective treatments in endemic areas highlights the need for continuous innovation. These emerging directions open up promising prospects not only for the optimization of antivenom therapy but also for the discovery of new peptides and toxins with therapeutic potential.

The evolution of modern technologies – from synthetic biology and recombinant expression to high-resolution structural methods – has profoundly transformed the study of animal venoms. These approaches allow not only the controlled reproduction of toxic peptides but also their structural optimization to obtain stable, selective, and therapeutically safe molecules. Thus, venoms are becoming increasingly clearly recognized as high-value biotechnological resources, providing models for the development of innovative drugs and paving the way for a new generation of bioactive therapies derived from nature.

Future progress depends on collaborative efforts between academic research, the biotechnology sector, and medical practice. Strengthening venom databases, developing standardised platforms for validating bioactivity, and expanding translational research infrastructure will be key to transforming these natural resources into a mature category of innovative therapies.

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VALORIZATION OF GRAPE BY-PRODUCTS FOR ORAL HEALTH: SUSTAINABLE DOSAGE FORMS FOR DENTAL THERAPY

University Teaching Assistant, Ph.D. Student Irinel LUNGU¹; Professor, Ph.D. Elena Lacramioara LISA¹

¹Centre in the Medical-Pharmaceutical Field, Faculty of Medicine and Pharmacy, "Dunarea de Jos" University of Galati, 800008 Galati, Romania,
Corresponding author; Irinel LUNGU: lun_iri@yahoo.com

Abstract

Grape by-products, including seeds, skins, and stems, are rich in polyphenols, flavonoids, and tannins with well-documented antioxidant, anti-inflammatory, and antimicrobial effects. This review explores their valorisation as sustainable bioactive sources for developing dosage forms aimed at improving oral health and supporting dental therapy. Experimental studies demonstrate that grape seed and skin extracts inhibit the growth of *Streptococcus mutans*, *Porphyromonas gingivalis*, and *Candida albicans*, suggesting their potential role in preventing caries, periodontal disease, and oral candidiasis. Their strong antioxidant capacity contributes to protecting gingival tissues from oxidative damage, while anti-inflammatory mechanisms aid in reducing gingival bleeding and inflammation. Recent formulations, such as polyphenol-enriched gels, mouth rinses, and mucoadhesive films, show encouraging results in maintaining oral microbial balance and promoting mucosal healing. In addition, the use of grape by-products aligns with circular bioeconomy principles by transforming agricultural residues into valuable therapeutic ingredients. The integration of these natural compounds into dental formulations represents a sustainable and innovative approach to oral care, combining efficacy, safety, and environmental responsibility.

Keywords: grape by-products, oral health, polyphenols, antimicrobial activity, dental therapy, sustainability

1. Introduction

The wine industry is one of the largest agri-food sectors worldwide, generating significant amounts of solid by-products, such as grape pomace, seeds, and skins, annually. These materials can represent up to 20–30% of the total mass of grapes processed during winemaking, thus constituting an important flow of agro-industrial residues (Lopes et al., 2025). In recent decades, the increased pressure on natural resources and the need to reduce waste have encouraged the development of sustainable strategies for the valorization of these by-products, in line with the principles of the circular economy. Thus, wine by-products have become an increasingly attractive source of bioactive compounds with potential applications in industry, medicine, cosmetics, and pharmacy.

In the field of oral health, interest in the use of natural extracts has increased significantly, amid concerns about bacterial resistance to antibiotics, the side effects of traditional antiseptics,

and the need for safer, more biocompatible, complementary approaches. Grape seed and skin extracts are recognized for their high content of polyphenols, especially proanthocyanidins, catechins, and anthocyanins, compounds with antimicrobial, anti-inflammatory, antioxidant, and remineralizing properties (Waghmare et al., 2023). Due to these characteristics, they are increasingly attracting attention as potential therapeutic agents in the prevention and treatment of common oral diseases, such as dental caries, gingivitis, periodontal disease, and dentinal sensitivity [1].

In parallel with the biological interest, modern pharmaceutical technology explores the integration of these extracts into sustainable administration forms: mucoadhesive gels, toothpastes, mouthwashes, bioadhesive films, or advanced controlled release systems. This approach not only capitalizes on underutilized natural resources but also contributes to the development of innovative formulations with high therapeutic potential.

In this context, the present paper aims to synthesize recent data on the phytochemical composition of grape by-products, their mechanisms of action relevant to oral health, and the opportunities for the development of sustainable pharmaceutical forms for dental therapy. The analysis aims to provide an integrated perspective on the potential of grape extracts to become key components in modern oral care and treatment products.

The general concept of valorizing wine by-products in oral health is presented in Figure 1, where the key steps are illustrated: obtaining polyphenolic compounds, their biological effects, and integration into sustainable pharmaceutical forms.”

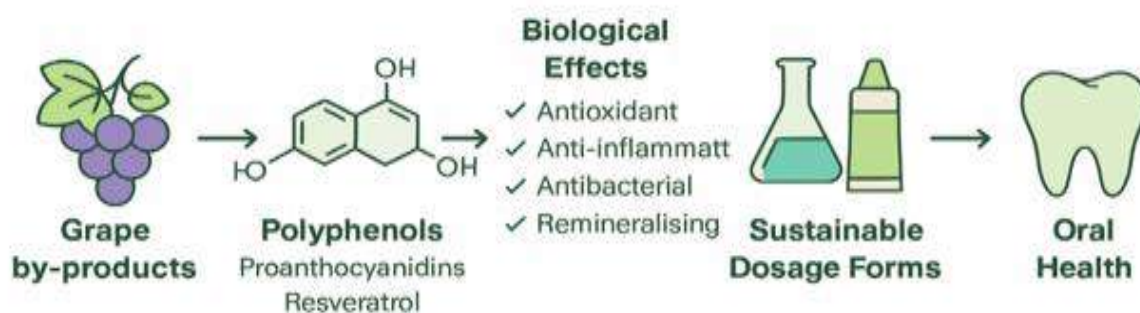


Fig.1 Schematic flow of the process of valorizing wine by-products for oral health.

The figure illustrates the valorization pathway of wine by-products, showing their conversion into polyphenol-rich extracts with antioxidant, anti-inflammatory, antibacterial, and remineralizing effects, which are subsequently formulated into sustainable dosage forms to support oral health.

2. Chemical Composition of Grape By-products

The by-products of winemaking processes, grape marc, seeds, and skins, are concentrated sources of bioactive compounds, particularly polyphenols, consisting of flavonoids, anthocyanins, catechins, and proanthocyanidins. These chemical components confer on grape extracts a broad spectrum of biological activities relevant to oral health, including antioxidant, antimicrobial, anti-inflammatory, and regenerative effects.

The exact composition of these by-products depends on numerous factors, such as grape variety, pedoclimatic conditions, fruit maturity, winemaking technology, and the extraction

method used. However, recent literature indicates that wine by-products are among the richest natural sources of polyphenols [2].

2.1 Tescovina and Phenolic Derivatives

Grape marc, defined as the solid mass remaining after crushing and pressing grapes, contains skins, seeds, pulp remnants, and stems. Chemically, grape marc is one of the most concentrated sources of phenols in the food industry, including flavonols (quercetin, kaempferol, anthocyanins, stilbenes (resveratrol), and proanthocyanidins [3].

Recent studies show that these bioactive components are present in high concentrations due to their natural localization in the skins and seeds. Anthocyanins, especially malvidin-3-glucoside, are responsible for the intense antioxidant activity and anti-inflammatory properties of the skins. In turn, proanthocyanidins in the tescovin show relevant antimicrobial activity in inhibiting oral bacteria involved in caries and periodontal disease [2].

2.2 Grape Seeds: Rich Sources of Proanthocyanidins

Grape seeds are recognized as one of the richest natural sources of proanthocyanidins. Oligomeric proanthocyanidins (OPCs) are compounds with strong antioxidant activity. Grape seed extract (GSE) typically contains between 70% and 80% proanthocyanidins oligomeric, along with flavanol monomers such as catechin and epicatechin [4].

These molecules exhibit a remarkable capacity to neutralize free radicals, surpassing in some studies the antioxidant potential of vitamins C and E [5]. In addition, the chemical structure of proanthocyanidins allows them to interact with structural proteins, especially dentinal collagen, stabilizing it and protecting it against enzymatic degradation.

In addition to these aspects, the seeds are also rich in fatty acids, tocopherols, and sterols, compounds with beneficial effects on tissue integrity and healing processes in the oral mucosa.

2.3 Grape Skins: Anthocyanins and Flavonoids

Grape skins are important sources of anthocyanins, natural pigments with high antioxidant potential. Anthocyanins are responsible for the color of red and black grapes, but also for the biological properties of extracts derived from these by-products.

Among the major compounds are malvidin, delphinidin, and petunidin, molecules with documented anti-inflammatory and antimicrobial effects. Extracts from the skins have demonstrated efficacy against some bacterial species associated with oral diseases, such as *Porphyromonas gingivalis* and *Streptococcus mutans* [6].

Also, flavonoids in the skin help protect oral epithelial cells and may help reduce vascular permeability and gingival inflammation.

2.4 Compositional Variability and Its Implications

The phytochemical composition of wine by-products is significantly influenced by the processing method. For example, fermentation processes affect the levels of anthocyanins in the skins and can modify the distribution of polyphenols in the pomace. Modern extraction methods, such as supercritical CO₂ extraction, ultrasound-assisted extraction, or microwave

extraction, allow the production of standardized extracts rich in active compounds, with minimal environmental impact [7].

This variability must be considered in the formulation of oral health products, as the stability and efficacy of the compounds are directly influenced by the chemical profile of the extract.

3. Biological Properties Relevant to Oral Health

Viticultural by-products, especially grape seeds and skins, contain a wide range of polyphenolic compounds with direct implications for oral health. These compounds exert multiple antibacterials, antioxidant, anti-inflammatory, remineralizing, and regenerative effects, which make them promising candidates for the development of oral therapeutic solutions.

3.1 Antibacterial Activity

One of the best-documented effects of proanthocyanidins is their ability to inhibit the growth of microorganisms involved in dental biofilm formation. Proanthocyanidins interfere with bacterial enzymes responsible for the synthesis of extracellular polysaccharides, significantly reducing the adhesion of *Streptococcus mutans*, the main etiological agent of dental caries [4].

Additionally, grape seed extract exhibits antimicrobial activity against *Lactobacillus* species, including *Lactobacillus rhamnosus*, thus contributing to the reduction of the production of organic acids responsible for enamel demineralization. This synergistic action: inhibition of biofilm formation and decrease in local acidity, places grape polyphenols among natural agents with high anticariogenic potential.

3.2 Antioxidant and Anti-inflammatory Effect

Oxidative stress and inflammation are essential factors in the progression of gingivitis and periodontal disease. Polyphenolic extracts from grape by-products exert a strong antioxidant action, reducing the level of reactive oxygen species (ROS) and protecting oral tissues from oxidative degradation [5].

In addition to neutralizing free radicals, proanthocyanidins modulate the inflammatory response by inhibiting key mediators such as interleukin IL-1 β and tumor necrosis factor TNF- α , both of which are involved in the destruction of periodontal tissues [4].

This Anti-inflammatory capacity indicates that grape extracts may have a protective role in the management of chronic inflammation and a potential adjunct to conventional periodontal treatments.

3.3 Remineralizing Potential

Another important mechanism by which grape seed extracts contribute to oral health is their ability to promote remineralization. Dentin. Proanthocyanidins act by stabilizing the dentinal collagen matrix, forming additional intermolecular bonds (" cross-links ") that increase the strength of the fibers and reduce their enzymatic degradation [8].

These extracts can also accelerate mineral re-deposition in demineralized areas, improving the integrity of the dentin structure and helping to reduce dentin hypersensitivity. Compared to other natural remineralizing agents, grape polyphenols have the additional advantage of

antioxidant and antimicrobial effects, making them extremely versatile in caries prevention and treatment applications.

3.4 Alveolar Bone Regeneration

In addition to their effects on dental soft and hard tissues, grape polyphenolic compounds have also shown potential in modulating bone metabolism. Proanthocyanidins can stimulate new bone formation and inhibit osteoclast differentiation and activity, thereby reducing bone resorption [9]. These properties are particularly relevant in the context of periodontal diseases, where alveolar bone loss is a central indicator of disease progression. At the same time, grape extracts can support post-surgical healing processes, including after tooth extractions or implants, accelerating bone regeneration and tissue stabilization.

4. Sustainable Pharmaceutical Forms for Oral Therapy

4.1 The Concept of Sustainability in Pharmaceutical Technology

The valorization of wine by-products in dental formulations is increasingly aligned with the principles of the circular economy, promoting efficient resource management and a significant reduction in agri-food waste. By transforming grape pomace, seeds, and skins into a source of bioactive compounds, a sustainable technological flow is created, which minimizes the impact on the environment [10]. In addition, the use of green extraction technologies, such as supercritical CO₂ extraction, ultrasound-assisted extraction, or ethanol-water solvent, contributes to obtaining high-quality extracts, with low energy costs and minimal toxicological risk [7]. These methods are increasingly appreciated in the pharmaceutical industry, where reducing the ecological footprint and process sustainability have become essential criteria.

4.2 Toothpastes and Gels

Topical formulations, such as gels and toothpastes, represent some of the most accessible and effective ways to locally administer polyphenolic compounds. Incorporation of grape seed extract into toothpastes has demonstrated a significant decrease in biofilm formation, as well as an overall improvement in oral hygiene, due to the antimicrobial and antioxidant activities of proanthocyanidins [1]. Mucoadhesive gels offer additional advantages, as they adhere to the oral mucosa for prolonged periods, allowing a gradual and controlled release of the active compounds. This extension of the contact time increases the therapeutic efficacy, especially in the treatment of gingivitis, localized inflammation, and dentinal sensitivity. In addition, gel formulations can be adapted for the inclusion of innovative delivery systems, such as microcapsules or nanoparticles. Polyphenols.

4.3 Mouthwashes and Gargles

Mouthwashes and gargles based on polyphenolic extracts are easy to administer and have a good distribution capacity throughout the oral cavity. They can reduce gingival inflammation, bacterial load, and halitosis through anti-inflammatory, antioxidant, and antimicrobial mechanisms. However, their efficacy depends largely on the stability of polyphenols in aqueous media, as they are sensitive to pH, oxygen, temperature, and light [3].

A pH that is too acidic can accelerate the degradation of compounds, while a pH that is too alkaline can affect their solubility. Thus, formulating a functional oral solution requires careful optimization of pH, stabilizers, and antioxidants to maintain the activity of the compounds during storage and use.

4.4 Buccal Films and Innovative Delivery Systems

Bioadhesive buccal films represent a modern and sustainable alternative to traditional formulations, offering the advantage of a controlled and prolonged release of active substances directly to the affected area. These thin, flexible, and biodegradable systems adhere to the oral mucosa and allow for discreet, comfortable, and effective administration. Films containing extracts from wine by-products can be used for localized inflammation, oral lesions, or periodontal treatment.

In parallel, innovative systems, such as nanoparticles, are increasingly being developed. Polyphenolic compounds or nano capsules can protect bioactive compounds from degradation and improving their penetrability in oral tissues. Studies show that these nanosystems can significantly increase the stability and bioavailability of polyphenols derived from grape pomace and seeds [7]. This type of approach could transform wine by-products into key ingredients for new-generation dental products.

5. Future Prospects and Directions

The integration of extracts obtained from wine by-products into oral health formulations represents a research direction with significant potential, but its evolution depends on overcoming major challenges. A first critical aspect is ***the standardization of polyphenolic extracts***, given the high variability of the chemical composition influenced by the grape variety, the cultivation conditions, the winemaking process, and the extraction methodology. Without rigorous standardization, the reproduction of experimental data and their transposition into clinical applications become difficult [2].

A second obstacle is ***the lack of large-scale clinical trials*** to confirm the promising results observed in in vitro experiments and preclinical studies. Most of the existing research focuses on antimicrobial, antioxidant, and remineralizing effects demonstrated in the laboratory, but clinical evidence remains limited. In the absence of well-designed, randomized controlled trials, the in vivo efficacy of grape by-product extracts in conditions such as caries, gingivitis, or periodontal disease cannot be definitively established [4].

Also, an important role is played by ***the optimization of pharmaceutical formulations*** containing polyphenolic extracts. These compounds are often susceptible to oxidative degradation, photolysis, or instability in aqueous media. Ensuring their stability during storage and after administration in the oral cavity represents a significant technological challenge. In addition, local bioavailability depends on the ability of the formulation to adhere to oral tissues and gradually release the active compounds, which is why mucoadhesive gels, bioadhesive films, and nano-delivery systems are increasingly being explored [7].

These challenges are compounded by issues related to ***industrial scalability***, regulation, and safety. Even though grape by-products are abundant and accessible, their processing under pharmaceutical conditions requires adequate infrastructure, strict quality controls, and validation of technological processes. In addition, consumer acceptability and sensory aspects

(color, taste, odor specific to grape extracts) may influence the adoption of these products in dental practice.

In this context, *interdisciplinarity* becomes an essential element. Cooperation between pharmaceutical technology, dentistry, biochemistry, the wine industry, and research in materials science can accelerate the development of innovative products capable of sustainably valorizing natural resources. This integrated approach favors not only the achievement of effective and safe therapeutic solutions but also the reduction of the ecological impact, transforming a stream of agri-food waste into a valuable resource for health.

6. Conclusions

Wine by-products constitute a remarkable and still underexploited resource of bioactive compounds, with significant potential in the prevention and management of oral diseases. Proanthocyanidins, catechins, anthocyanins, and other polyphenols extracted from grape pomace, seeds, and skins have demonstrated a wide spectrum of beneficial activities, including antimicrobial, antioxidant, anti-inflammatory, remineralizing, and regenerative effects. These properties support the use of wine extracts as active ingredients in the development of modern and sustainable products for oral hygiene and dental therapy.

The integration of these compounds into innovative pharmaceutical forms: mucoadhesive gels, bioadhesive films, oral solutions, or nanosystems, offers promising prospects for increasing therapeutic efficacy and expanding the portfolio of green products with reduced ecological impact. However, despite the promising results reported in recent literature, their translation into clinical practice requires further investigation.

In this regard, *rigorous clinical studies are necessary* to validate the effects observed in vitro and in vivo, as well as *the optimization of standardization and formulation procedures* to ensure the stability, bioavailability, and safety of the active compounds. The integrated, interdisciplinary approach between pharmaceutical technology, dentistry, and the wine industry has the potential to accelerate the development of high-performance, sustainable therapeutic solutions adapted to current oral health needs.

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THE USE OF MEDICINAL PLANTS FROM THE TRANSYLVANIAN PLAIN IN MODERN DENTAL TREATMENTS

**Assoc. Prof. Carmen GÂLEA Ph.D.¹; Assoc. Prof. Ramona Flavia RAȚIU Ph.D.²;
Ph.D. Student Mioara DÂRNEA³; Assist. Prof. Sorana Maria BUCUR Ph.D.¹**

¹Department of Dentistry, Faculty of Medicine, Dimitrie Cantemir University of Târgu Mureș, 540545 Târgu Mureș, România.

²UDC Faculty of Geography;

³Department of Implantology, Removable Protheses, Dental Protheses Technology, "Grigore T. Popa" University of Medicine and Pharmacy, Iasi, Romania.

Corresponding - Ramona Flavia Ratiu: ratiuflavia@yahoo.com; Mioara Darnea: miodar2@yahoo.com

Abstract

Objective of the study: Our work aims to analyze medicinal plants from the Transylvanian Plain and their applications in dentistry in order to obtain modern pharmaceutical forms such as sawtooth microneedles, liposomal creams, mucoadhesive patches and copolymer membranes. Material and method: the identification of species with a wide distribution was carried out both on the basis of specialized studies and by mapping.

Results: Following the studies, we highlighted 10 species of medicinal plants more commonly distributed in the Transylvanian Plain: thyme – *Thymus vulgaris* (family Lamiaceae), valerian – *Valeriana officinalis* (family Valerianaceae), yarrow – *Achillea millefolium* (family Asteraceae), St. John's wort – *Hypericum perforatum* (family Hyperaceae), white mallow – *Althea officinalis* (family Malvaceae), mistletoe – *Viscum album* (family Santalaceae), three-spotted violet – *Viola tricolor* (family Violaceae), dandelion – *Taraxacum officinale* (family Asteraceae), hawthorn – *Crategus monogyna* (family Rosaceae), elder – *Sambucus nigra* (family Adoxaceae). Among the listed species, valerian (*Valeriana officinalis*), yarrow (*Achillea millefolium*) and thyme (*Thymus vulgaris*) find applications in dentistry. Within the project, we proposed modern pharmaceutical forms with applicability in oral cavity diseases such as oral cancers, osteoarthritis of the temporomandibular joint, pericoronitis and for maintaining oral health.

Conclusions: The Transylvanian Plain is an excellent source for enriching the therapeutic arsenal with state-of-the-art medicinal products whose adverse effects are minimal.

Keywords: medicinal plants, Transylvanian Plain, innovative medicinal forms, oral pathology.

Introduction

The Transylvanian Plain is the major unit of the Transylvanian Colline Depression, bounded by the Someșului Mare Corridor in the north, the Bistrița and Reghin Hills in the west, the Mureș Corridor in the south and the Arieș and Someșului Mic Corridor in the west, a territory occupied by 90% of agricultural land (arable land, pastures and hayfields). In the Transylvanian

Plain, the vegetation typology and its spatial extension are expressions of the topoclimate, soil and monoclinal relief.

Light, slope exposure and thermal preferences of the species analyzed

The geocological characteristics of the species – such as the humidity regime, soil type, light availability, slope exposure and thermal preferences – significantly influence the distribution, density and regeneration capacity of natural populations. The analysis of thermal preferences shows that most of the analyzed species fall into the category of thermophilic and moderate ones (table), the Transylvanian Plain being characterized by average annual temperatures of 8-9 degrees C [1].

Thyme *Thymus serpyllum*, St. John's wort *Hypericum perforatum* and hawthorn *Crataegus monogyna* are pronounced thermophilic species, adapted to warmer regions and S-SW and W sun exposures [2]. In contrast, valerian *Valeriana officinalis*, mallow *Althaea officinalis* and *Viola tricolor*, pansy, have lower thermal requirements, developing optimally in cool and humid areas of the cuesta reverses of the Transylvanian Plain, with N-NE (shaded) and shaded exposures.

The degree of light is a critical factor for photosynthesis and for the synthesis of active principles. Heliophilous species, such as St. John's wort *Hypericum perforatum* and hawthorn *Crataegus monogyna*, prefer open habitats, with maximum solar exposure, being characteristic of slopes with southern or southwestern exposure [2]. Thyme, *Thymus serpyllum* shows similar behavior, developing on sunny meadows and dry soils.

Semi-umbryphilic or umbryphilic species, such as *Valeriana officinalis*, *Achillea millefolium* and *Sambucus nigra*, are frequently associated with N-NE or E exposures, where solar radiation is moderate. In forest habitats, mistletoe *Viscum album* benefits from the shade of the host tree crowns, which determines a relatively stable microclimate, with reduced thermal variations.

Table 1. Geocological characteristics of medicinal plants

Plant	Humidity	Soil	Luminosity/ Exhibit	Temperature
<i>Thymus serpyllum</i> Chimney sweeper	dry	arid, sandy, rocky	sunny	thermophilic
<i>Achillea millefolium</i> Milfoil	mesophyll	Varied	N-NE, E, penumbra	moderate
<i>Hypericum perforatum</i> Rattles	dry	Calcicol	sunny	thermophilic
<i>Althaea officinalis</i> Mallow	marshy	sandy, clayey	neutral	cool
<i>Viscum album</i> Mistletoe	host dependency	on the threes	shady	resistant
<i>Viola tricolor</i> Pansy	moderate	acid/ neutral / sandy	neutral	cool-moderate
<i>Taraxacum officinale</i> Dandelion	moderate	wet, varied	tolerant	mesotherm
<i>Crataegus monogyna</i> Hawthorn	low	Varied	sunny	termophylic
<i>Sambucus nigra</i> Elder	moderate	fertile	N-NE, E	moderate
<i>Valeriana officinalis</i> Valerian	high	sandy, clayey , rich in humus	penumbra	cool

Humidity Regime and Water Adaptation

The most significant part of the Plain is characterized by precipitation ranging between 600-700mm/year [1]. Water resources are scarce in Transylvania due to the poverty of surface and groundwater and their modest quality [3]. Xerophilous species, such as *Thymus serpyllum* (thyme) and *Hypericum perforatum* (St. John's wort), are characteristic of dry meadows, with low humidity, developing predominantly on sunny slopes and well-drained soils. In contrast, hygrophilous species, among which *Valeriana officinalis* and *Althaea officinalis* stand out, are dependent on a high precipitation regime and moist, organic or loamy-sandy soils.

Mesophilic species, such as *Achillea millefolium* (yarrow), *Sambucus nigra* (elderberry) and *Taraxacum officinale* (dandelion), occupy an intermediate position, being adapted to habitats with moderate humidity, especially forest edges, microdepressions or shady grassy areas [2].

Soil type is a determining factor for germination, population stability and the production of secondary metabolites of phytotherapeutic interest. Light, sandy or stony soils are preferred by xerophilous species, such as thyme *Thymus serpyllum*. St. John's wort, *Hypericum perforatum*, is a calcic species, indicating the presence of calcium-rich substrates and avoiding acidic soils.

Hygrophilous species, such as valerian (*Valeriana officinalis*) and marshmallow (*Althaea officinalis*), require deep, permeable, humus-rich soils, characterized by large water reserves. Other species, such as *Viola tricolor*, have high edaphic plasticity, being able to thrive in both acidic and neutral soils. In the case of mistletoe (*Viscum album*), the edaphic requirements are indirect, depending on the host species on which it grows, usually mature deciduous trees.

Synthesis of Geocological Distribution

Combining all the factors analyzed, a diversified ecological structure is outlined:

- **Dry and warm habitats, on slopes with S-SW (sunny) and W (partially sunny) exposure** – favorable for xerophilous heliophilous species (thyme, St. John's wort, hawthorn).
- **Humid and cool habitats** – dominant for hygrophilous species (valerian, great mallow).
- **Mesophile, semi-shaded habitats**, on slopes with N-NE (shaded) and E (partially shaded) exposure – specific to yarrow, dandelion, elderberry.
- **Tree-dependent habitats** – characteristic of mistletoe, a parasitic species with distinct eco physiological particularities.

This geopedological classification highlights that the distribution of medicinal plants is not random, but results from the complex convergence of climatic, edaphic and geomorphological factors. Understanding these relationships allows both a more precise assessment of the phototherapeutic potential of some regions, and fundamental to sustainable strategies for the conservation and valorisation of plant biodiversity.

Medicinal Plants with a Wide Distribution in the Transylvanian Plain

Following the mappings, we highlighted 10 more common medicinal plant species spread in the Transylvanian Plain: thyme – *Thymus serpyllum* (family *Lamiaceae*), valerian – *Valeriana officinalis* (family *Valerianaceae*), yarrow – *Achillea millefolium* (family *Asteriaceae*), *Hypericum perforatum* (family *Hypericaceae*), white mallow – *Althaea officinalis* (family *Malvaceae*), mistletoe – *Viscum album* (family *Santalaceae*), three-spotted violet – *Viola*

tricolor (family *Violaceae*), dandelion – *Taraxacum officinale* (family *Asteraceae*), hawthorn – *Crataegus monogyna* (family *Rosaceae*), elder – *Sambucus nigra* (family *Adoxaceae*).

Species Rich in Essential Oils

Among the listed species, valerian, yarrow and thyme find applications in dentistry. Within the project, we proposed modern pharmaceutical forms with applicability in oral cavity diseases such as oral cancers, osteoarthritis of the temporomandibular joint, pericoronitis and for maintaining oral health. *Thymus serpyllum*, thyme (family *Lamiaceae*) is a perennial plant found in the flora of Europe and North Africa (Mediterranean region) used in folk medicine as an antiseptic, anthelmintic, diuretic, tonic, sedative, immunostimulant and analgesic. From a phytochemical point of view, thyme contains essential oils (borneol, carvacrol, cymene, linalool, thymol), flavonoids (apigenin and luteolin) and tannins [4]- [6].

Thymus serpyllum, thyme (family *Lamiaceae*) is a perennial plant that stands out for its antimicrobial action, significantly reducing the colonies of *C. albicans*, *S. aureus*, *S. mutans*, *E. faecalis*. It also has bacteriostatic and bactericidal action, especially on 15 Gram-negative and Gram-positive strains [7]. In the oral cavity, the strongest action was shown on *S. mutans*. The mechanism of action is based on the damage to the bacterial cell membrane (due to phenolic compounds and flavonoids) and on the damage to the enzymatic system (due to phenols and tannins, [8]). Applications in dentistry refer to its use as a control agent on bacterial plaque, restorative material, disinfectant in orthodontics, treatment of dysplastic lesions, endodontic irrigant, in pulpotomy and in the biosynthesis of nanoparticles [9].

Valleriana officinalis, valerian (family *Caprifoliaceae*) is a herbaceous, perennial species with delicate, white-pink flowers with a pungent odor. We find it in the spontaneous flora of Asia and Europe, being cultivated for over 2000 years for its relaxing and sedative properties. The most important phytoconstituents are: volatile oil, valeric acid and isovaleric acid as well as alkaloids (catinine and valerinone). Valerian is known to have the following pharmacological actions: anxiolytic, sedative, antiarrhythmic, analgesic. Studies show that valeric acid and valepotriates from valerian root can modulate the activity of gamma aminobutyric acid in the brain, improving mood and inducing calm [10]. For therapeutic purposes, valerian can be found in the form of teas, capsules, tablets, tinctures, extracts and essential oils. In dentistry, valerian in doses of 100 mg is used for its anti-anxiety action, to which is added a slight hypotensive action [11].

Achillea millefolium, yarrow, (family *Asteraceae*) is a herbaceous plant with a typical appearance. The leaves are dark green with serrated edges, and the flowers are grouped in dense, white, pink inflorescences with a sweet, bitter odor. Yarrow has been known since antiquity, being used by Dioscorides for its haemostatic action and by Hippocrates for sitz baths and bleeding haemorrhoids. The name *Achillea* comes from Achilles, the hero of the Trojan War, who used the plant to treat the wounds of his soldiers [12].

The stems and leaves of the species *Achillea millefolium* are rich in tannins, while the flowers are rich in essential oil in whose composition we find azulene and achilleic lactones (with anti-inflammatory action), tannins, flavonoids and alkaloids. stimulation of the immune system, improvement of cardiac function (due to vasodilator properties), anti-inflammatory action especially at the genitourinary level, haemostatic, astringent and healing action [13]- [16]. It is beneficial in treating urinary tract diseases and respiratory tract inflammations. The forms in which yarrow can be consumed are tea, tincture, compresses and baths, capsules and tablets, ointments and creams. At the oral cavity level, *Achillea millefolium* extracts have been

tested for anticancer action on osteosarcoma cells by reducing their viability, inducing apoptosis and migration, which evidences the real potential in anticancer therapy.

Conclusions

Thyme, yarrow and valerian species have essential oils in common as phytoconstituents and can be used in dentistry in various pharmaceutical forms: microneedles, liposomal creams, nanodesigned mucoadhesive patches and copolymer membranes. All these forms, which we have not proposed as optimization systems, represent innovative forms. The benefits of controlled release systems refer to achieving a therapeutic action, without generating adverse effects or overdose.

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RELATIONSHIP BETWEEN DENTAL ANXIETY AND CHILD COOPERATION DURING DENTAL TREATMENTS – OBSERVATIONAL CLINICAL STUDY

Associate Professor, Ph.D. Sorana Maria BUCUR¹; University Teaching Assistant, Ph.D., Student Alexandra Camelia POGĂCIAN-MAIER²; Lecturer, Ph.D. Claudia NISTOR¹; Associate Professor, Ph.D. Carmen GÂLEA¹

¹*Department of Dentistry, Faculty of Medicine, Dimitrie Cantemir University of Târgu Mureş, 540545 Târgu Mureş, România;*

²*Doctoral School, University of Medicine and Pharmacy “Iuliu Hațieganu” Cluj-Napoca, 400347 Cluj-Napoca, Romania
Corresponding author: Alexandra Camelia Pogăcian-Maier: alemaier10@yahoo.com; Claudia Nistor: nistor_ca@yahoo.com*

Abstract

Background and Objectives: Dental anxiety can significantly influence children's behaviour and cooperation during treatment, affecting oral health outcomes. The relationship between common oral habits and dental anxiety or behavioural responses in children remains unclear. This study aimed to examine associations between oral habits and dental anxiety and behaviour, using validated psychological instruments, and to identify predictors of these outcomes. **Materials and Methods:** A cross-sectional study was conducted on 162 children aged 4–10 years at the Dimitrie Cantemir University Dental Clinic. Dental anxiety was assessed using the Modified Dental Anxiety Scale (MDAS), and cooperative behaviour was evaluated using the Behaviour Assessment System for Children (BASC) subscales for adaptability and social skills. Information on oral habits (bruxism, thumb sucking, nail biting), parental education, previous dental treatment experiences, and type of current procedure was collected. Statistical analyses included Spearman correlation, chi-square tests, and multiple linear regression ($\alpha = 0.05$). **Results:** The mean MDAS score was 12.8 ± 4.3 , indicating mild to moderate anxiety levels. BASC subscale scores for cooperation averaged 45.6 ± 8.2 , reflecting generally adequate behaviour. Dental anxiety was inversely correlated with cooperative behaviour ($r = -0.54$; $p < 0.001$). Multiple regression identified previous painful dental experiences, prior cooperation at earlier visits, and invasiveness of current treatment as significant predictors of both anxiety and behaviour ($p < 0.05$). No significant associations were observed between oral habits and either anxiety or cooperation. **Conclusions:** In this clinical population, oral habits were not associated with dental anxiety or cooperative behaviour. Previous experiences and the treatment procedures influence children's anxiety. These findings highlight the importance of considering behavioural history and procedural factors when planning paediatric dental care.

Keywords: dental anxiety; child behaviour; MDAS; BASC; oral habits; bruxism; thumb sucking; paediatric dentistry.

Introduction

Dental anxiety in children is a well-documented phenomenon that can adversely affect dental attendance, cooperation during treatment, and long-term oral health outcomes [1,2].

Anxiety-related behavioural challenges often complicate clinical management, leading to prolonged appointments, incomplete treatments, or avoidance of dental care altogether. Understanding the determinants of dental anxiety and cooperative behaviour in children is therefore of significant importance for paediatric dentists and oral health professionals [1-3]. Previous research has demonstrated that dental anxiety is multifactorial, influenced by developmental stage, temperament, parental attitudes, previous dental experiences, and characteristics of dental procedures themselves. Painful or invasive treatments, in particular, have been identified as strong contributors to fear and negative behavioural responses. Conversely, positive early dental encounters and supportive communication strategies may promote adaptive coping and cooperation [1]- [5].

Oral habits such as bruxism, thumb sucking, and nail biting are common during early childhood and have been associated with emotional regulation, stress, and anxiety in non-dental contexts [4,6,7]. These habits are often viewed as self-soothing behaviours that may reflect underlying psychological distress or coping mechanisms [7,8]. However, evidence linking such oral habits to dental anxiety or cooperative behaviour during dental treatment remains limited and inconsistent. Some studies suggest a relationship between anxiety-related traits and parafunctional habits, while others report no significant associations [4,6,7,8].

Validated psychological instruments are essential for accurately assessing dental anxiety and behaviour in children. The Modified Dental Anxiety Scale (MDAS) is widely used and has demonstrated good reliability and validity across age groups [9,10]. Similarly, the Behaviour Assessment System for Children (BASC) provides standardized measures of adaptability and social skills, which are relevant indicators of cooperative behaviour in clinical settings [11].

Given the existing gaps in the literature, this study aimed to examine the relationships between common oral habits and dental anxiety, and cooperative behaviour in children aged 4–10 years. Additionally, the study sought to identify significant predictors of dental anxiety and behaviour, including previous dental experiences, parental education, and the invasiveness of dental procedures. Understanding these associations may assist clinicians in developing individualized behavioural management strategies and improving paediatric dental care outcomes.

Materials and Methods

Study Design and Participants

A cross-sectional observational study was conducted at the Dimitrie Cantemir University Dental Clinic. The study population consisted of children aged between 4 and 10 years who attended the clinic for routine or therapeutic dental care over six months. A total of 162 children were included based on predefined inclusion and exclusion criteria.

Inclusion criteria were: (1) age between 4 and 10 years, (2) ability to understand and respond to age-appropriate psychological assessments, and (3) informed consent provided by a parent or legal guardian. Children with diagnosed neurodevelopmental disorders, cognitive impairments, or systemic medical conditions that could influence behaviour were excluded.

Ethical Considerations

The study protocol was reviewed and approved by the institutional ethics committee of Dimitrie Cantemir University. All procedures were conducted in accordance with the

Declaration of Helsinki. Written informed consent was obtained from parents or guardians before participation, and verbal assent was obtained from children when appropriate.

Data Collection. Dental Anxiety Assessment

Dental anxiety was assessed using the Modified Dental Anxiety Scale (MDAS), a five-item questionnaire measuring anxiety related to specific dental situations. Each item is scored on a 5-point Likert scale, with total scores ranging from 5 to 25. Higher scores indicate greater levels of dental anxiety. The MDAS was administered in a child-adapted format with parental assistance for younger participants.

Behavioural Assessment

Cooperative behaviour was evaluated using selected subscales from the Behaviour Assessment System for Children (BASC), specifically adaptability and social skills. These subscales were chosen due to their relevance in assessing children's ability to adjust to new situations and interact appropriately with healthcare providers. Scores were standardized according to age norms, with higher scores reflecting more adaptive and cooperative behaviour.

Oral Habits and Background Variables

Information regarding the presence of oral habits, including bruxism, thumb sucking, and nail biting, was collected through parental questionnaires. Additional variables included parental education level, previous dental treatment experiences (categorized as positive, neutral, or painful), prior cooperation during dental visits, and the type of dental procedure performed at the current visit (non-invasive vs. invasive).

Statistical Analysis

Data were analysed using statistical software with a significance level set at $\alpha = 0.05$. Descriptive statistics were calculated for all variables. Spearman's rank correlation coefficient was used to examine the relationship between dental anxiety and cooperative behaviour. Chi-square tests assessed associations between categorical variables. Multiple linear regression analyses were performed to identify predictors of dental anxiety and behaviour, with MDAS and BASC scores as dependent variables.

Results

Sample Characteristics

The study included 162 children aged 4–10 years (mean age: 6.9 ± 1.8 years), with an almost equal gender distribution (50.6% boys, 49.4% girls). Oral habits were reported in 58.6% of participants, with nail biting being the most prevalent habit. Most parents had completed secondary or higher education.

Table 1 presents the demographic characteristics and distribution of oral habits in the study sample of 162 children. The gender distribution was nearly equal, with 82 boys (50.6%) and 80

girls (49.4%). The mean age of the participants was 6.9 ± 1.8 years, reflecting a predominantly early school-age population.

More than half of the children (58.6%) were reported to exhibit at least one oral habit, while 41.4% had no oral habits. Nail biting was the most prevalent habit, observed in 28.4% of participants, followed by thumb sucking (19.1%) and bruxism (11.1%).

Table 1. Demographic characteristics and oral habits of the study sample (N = 162)

Variable	n (%)
Sex	
Boys	82 (50.6)
Girls	80 (49.4)
Age (years)	
Mean $\pm$ SD	6.9 ± 1.8
Presence of oral habits	
None	67 (41.4)
Any oral habit	95 (58.6)
— Nail biting	46 (28.4)
— Thumb sucking	31 (19.1)
— Bruxism	18 (11.1)
Parental education	
Primary	28 (17.3)
Secondary	74 (45.7)
Higher education	60 (37.0)

Regarding parental education, most parents had completed secondary education (45.7%), followed by higher education (37.0%), whereas a smaller proportion had primary education only (17.3%).

Dental Anxiety and Cooperative Behaviour

The mean MDAS score was 12.8 ± 4.3 , corresponding to mild to moderate dental anxiety. BASC adaptability and social skills scores averaged 45.6 ± 8.2 , indicating generally adequate cooperative behaviour.

A statistically significant inverse correlation was found between dental anxiety and cooperative behaviour (Spearman $r = -0.54$; $p < 0.001$).

Table 2. Descriptive statistics of MDAS and BASC scores

Variable	Mean $\pm$ SD	Range
MDAS total score	12.8 ± 4.3	5–25
BASC cooperation score	45.6 ± 8.2	30–65

Associations between Oral Habits, Anxiety and Behaviour

No statistically significant differences were observed in MDAS or BASC scores between children with and without oral habits ($p > 0.05$). This finding remained consistent across individual habit categories.

Table 3. Comparison of dental anxiety and behaviour by oral habit presence

Oral habit status	MDAS (Mean $\pm$ SD)	BASC (Mean $\pm$ SD)	p-value
No oral habits (n = 67)	12.5 $\pm$ 4.1	46.1 $\pm$ 8.0	
Any oral habit (n = 95)	13.0 $\pm$ 4.5	45.3 $\pm$ 8.4	>0.05

Predictors of Dental Anxiety and Cooperative Behaviour

Multiple linear regression analysis identified previous painful dental experiences, poor cooperation at earlier visits, and invasive dental procedures as significant predictors of increased dental anxiety and reduced cooperative behaviour ($p < 0.05$). Oral habits and parental education were not significant predictors.

Table 4. Multiple linear regression analysis predicting dental anxiety (MDAS score)

Predictor	β	SE	p-value
Previous painful dental experience	0.41	0.09	<0.001
Poor prior cooperation	0.32	0.08	0.002
Invasive dental procedure	0.29	0.07	0.004
Oral habits	0.06	0.05	0.28
Parental education	-0.04	0.06	0.44

In Figure 1, bars represent standardized regression coefficients (β) for predictors of dental anxiety. Error bars indicate standard errors. Previous painful dental experience, poor prior cooperation, and invasive dental procedures were significant predictors of increased dental anxiety, whereas oral habits and parental education were not significant.

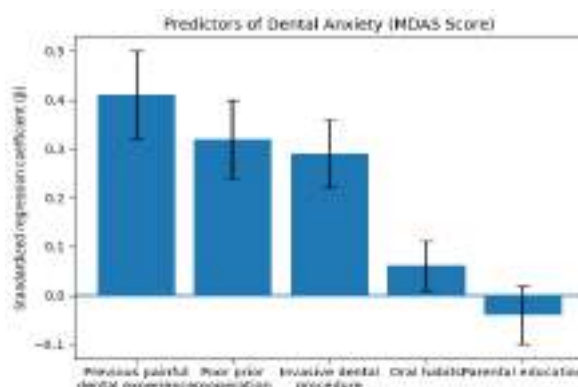


Figure 1. Predictors of dental anxiety (MDAS score) based on multiple linear regression analysis

Discussion

The present study confirms a robust inverse relationship between dental anxiety and cooperative behaviour in children, reinforcing existing evidence that anxiety significantly compromises behavioural adaptation during dental treatment. This finding aligns with previous reports by Klingberg [12] and Cianetti et al. [13], who demonstrated that anxious children exhibit greater behavioural resistance and treatment avoidance.

Contrary to common assumptions, no association was identified between oral habits (bruxism, thumb sucking, nail biting) and dental anxiety or cooperation. Although oral habits have been linked to emotional stress and anxiety in psychological and paediatric literature, their relevance appears to be context dependent. Similar findings were reported by Goyal et al. [14]

and Serra-Negra et al. [15], who found weak or inconsistent relationships between parafunctional habits and situational anxiety in dental settings. This suggests that dental anxiety represents a domain-specific fear rather than a general manifestation of emotional dysregulation.

Experiential factors emerged as the strongest predictors of both dental anxiety and cooperative behaviour. Previous painful dental experiences were the most influential variable, corroborating the conditioning model of dental fear development described by Rachman [16] and supported by longitudinal studies in paediatric dentistry. Negative early encounters can lead to anticipatory anxiety, behavioural avoidance, and long-term dental fear persisting into adolescence and adulthood [16].

The invasiveness of the current dental procedure was also a significant predictor, consistent with findings from Huang et al., who demonstrated higher anxiety levels during procedures involving local anaesthesia, extractions, or rotary instruments. These results emphasize the importance of pain control, minimally invasive dentistry, and behavioural guidance techniques, especially in young children.

Interestingly, parental education level did not significantly predict child anxiety or cooperation. While some studies report associations between parental socioeconomic factors and child dental fear, others suggest that parental attitudes and anxiety—rather than education level per se—play a more decisive role [18,19]. As parental dental anxiety was not directly assessed in this study, its potential mediating effect cannot be excluded.

The cross-sectional design limits causal interpretation, and reliance on parental reporting for oral habits may introduce reporting bias. Nevertheless, the use of validated instruments (MDAS and BASC), a clinically relevant sample, and multivariate analysis strengthens the validity of the findings.

Future research should adopt longitudinal designs to assess the temporal relationship between early dental experiences, anxiety trajectories, and behavioural outcomes [20]. Incorporating direct behavioural observations, child self-reports, and parental anxiety measures would further enhance understanding and support the development of targeted behavioural management strategies.

Conclusions

Within the limitations of this study, common oral habits such as bruxism, thumb sucking, and nail biting were not associated with dental anxiety or cooperative behaviour in children aged 4–10 years. Dental anxiety was moderately prevalent and showed a strong negative association with behavioural adaptability during treatment.

Previous painful dental experiences, prior behavioural responses, and the invasiveness of dental procedures emerged as key predictors of both anxiety and cooperation. These findings emphasize the importance of minimizing discomfort, fostering positive early dental experiences, and tailoring behavioural management strategies to each child's history and treatment needs.

Integrating psychological assessment tools into routine paediatric dental practice may enhance clinicians' ability to anticipate behavioural challenges and improve overall treatment outcomes.

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EFFECTIVENESS OF MINIMALLY INVASIVE TREATMENT TECHNIQUES FOR DENTAL CARIES IN CHILDREN – COMPARATIVE CLINICAL STUDY BETWEEN THE HALL TECHNIQUE AND CONVENTIONAL TREATMENTS

Associate Professor, PhD Sorana Maria BUCUR¹; University Teaching Assistant, PhD Student Alexandra Camelia POGĂCIAN-MAIER^{2*}; Professor, Ph.D. Alexandrina MUNTEAN³

¹*Department of Dentistry, Faculty of Medicine, Dimitrie Cantemir University of Târgu Mureș, 540545 Târgu Mureș, România;*

²*Doctoral School, University of Medicine and Pharmacy “Iuliu Hațieganu” Cluj-Napoca, 400347 Cluj-Napoca, Romania;*

³*Department of Paediatric Dentistry, Iuliu Hațieganu University of Medicine and Pharmacy, 31 A. Iancu Street, 400083 Cluj-Napoca, Romania*

Corresponding author: Alexandra Camelia Pogăcian-Maier: alemaier10@yahoo.com

Abstract

Background: In Romania, most paediatric oral health services are delivered through primary dental care settings, yet limited evidence exists regarding the comparative success of restorative interventions for carious primary molars. **Aim:** To evaluate the clinical performance of two restorative approaches for managing carious primary molars in children attending primary care dental clinics. **Methods:** A controlled experimental study was conducted on 38 children aged 5–8 years. Each participant received treatment for one carious primary molar using either a plastic restorative material (PRM) or a preformed stainless-steel crown applied with the Hall Technique (HT). Clinical and radiographic assessments were performed after a mean follow-up period of 24 months (range: 20–31 months). Restorations were categorized as successful or failures. Data were analyzed using Chi-square tests. **Results:** Thirty-five children (92%) completed follow-up. Failure rates were significantly higher in the PRM group (29%) than in the HT group (9%) ($p < 0.05$). Deep lesions with marginal ridge breakdown showed a markedly greater proportion of major failures (31%) compared with shallow lesions without breakdown (2%) ($p < 0.001$). Among deep lesions, HT restorations demonstrated superior longevity relative to PRM. **Conclusions:** The Hall Technique yielded significantly higher success and lower failure rates than conventional PRM restorations, particularly in managing deep carious lesions.

Keywords: Hall Technique; Primary molars; Dental caries; Restorative outcomes; Primary care dentistry.

Introduction

Dental caries remains the most prevalent chronic disease of childhood worldwide and continues to pose a substantial public health burden in Eastern Europe, including Romania. Primary molars are particularly vulnerable due to their morphology, thinner enamel, and prolonged exposure to cariogenic challenges. If left inadequately treated, caries in primary teeth can lead to pain, infection, impaired mastication, and negative impacts on quality of life and school performance [1-3].

In Romania, the majority of pediatric dental care is delivered within primary care dental clinics, often under conditions of limited time, financial constraints, and variable access to advanced materials or specialist services. Conventional restorative management of carious primary molars commonly relies on plastic restorative materials (PRM), such as glass ionomer cements or resin-based composites [4,5]. While these materials are widely used, their longevity in primary molars, especially in deep or multisurface lesions, has been questioned, with failure frequently attributed to marginal breakdown, secondary caries, and material loss [6,7].

In contrast, preformed stainless-steel crowns (SSCs), particularly when placed using the minimally invasive Hall Technique (HT), have gained increasing international acceptance [8-10]. The Hall Technique involves cementation of a preformed crown without caries removal, tooth preparation, or local anesthesia, sealing the carious lesion, and arresting disease progression [8-10]. Multiple studies conducted in secondary care or academic settings have demonstrated superior survival rates of HT crowns compared to conventional restorations. [8-10]. However, evidence from real-world primary care environments, especially in Eastern European contexts, remains scarce [11].

The present study aimed to evaluate and compare the clinical and radiographic performance of PRM restorations and Hall Technique crowns in managing carious primary molars among children treated in Romanian primary dental care clinics. A secondary objective was to analyze the influence of lesion depth and marginal ridge integrity on restoration outcomes.

Materials and Methods

Study Design and Setting

A controlled experimental clinical study was conducted in primary dental care clinics affiliated with a university dental network in Romania. The study followed CONSORT-adapted principles for non-randomized interventional studies and adhered to ethical standards for research involving children.

Ethical Approval

Ethical approval was obtained from the Institutional Research Ethics Committee. Written informed consent was secured from parents or legal guardians, and verbal assent was obtained from participating children.

Study Population

A total of 38 children aged 5–8 years were recruited between January and June. Inclusion and exclusion criteria were as follows:

Inclusion criteria:

- Presence of at least one carious primary molar requiring restorative treatment
- Cooperative behavior sufficient to permit treatment without pharmacological sedation
- Absence of spontaneous pain or acute infection

Exclusion criteria:

- Children with systemic diseases affecting oral health

- Teeth with signs of irreversible pulpitis or dental abscess
- Radiographic evidence of advanced pathological root resorption
- Intervention Groups
- Each child received treatment for *one carious primary molar*, allocated to one of two restorative approaches:

Plastic Restorative Material (PRM) Group

- Conventional caries removal
- Restoration with high-viscosity glass ionomer cement or resin-based composite
- Use of local anesthesia and rotary instrumentation when required

Hall Technique (HT) Group

- No caries removal or tooth preparation
- Cementation of a preformed stainless-steel crown using glass ionomer luting cement
- No local anesthesia
- Lesion Classification
- Lesions were classified based on clinical and radiographic findings:

Shallow lesions: confined to dentin without marginal ridge breakdown

Deep lesions: extending to the inner third of dentin and/or associated with marginal ridge breakdown

Follow-Up and Outcome Assessment

Clinical and bitewing radiographic evaluations were performed after a mean follow-up period of **24 months** (range: 20–31 months).

Restorations were categorized as:

Successful: restoration intact, asymptomatic tooth, no radiographic pathology

Minor failure: repairable defect without pulpal involvement

Major failure: pain, abscess, pulpal pathology, or restoration loss requiring extraction or pulp therapy

Statistical Analysis

Data were analysed using statistical software. Descriptive statistics were calculated, and group comparisons were performed using Chi-square tests. Statistical significance was set at $p < 0.05$.

Results

Participant Flow and Follow-Up

Out of 38 enrolled children, **35 (92%) completed the follow-up**. Three participants were lost to follow-up due to relocation or non-attendance.

Overall Restoration Outcome

After a 24-month follow-up, a total of 35 restorations were evaluated (Figure 1, Table 1). Overall, 28 restorations (80%) were classified as successful, while 7 restorations (20%) failed. When outcomes were analyzed by restoration type, the Hall Technique demonstrated a higher success rate, with 16 out of 18 restorations (91%) remaining successful and only 2 failures (9%). In contrast, PRM restorations showed a lower success rate, with 12 of 17 restorations (71%) classified as successful and 5 failures (29%).

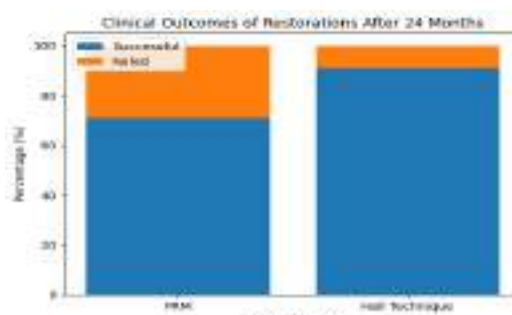


Figure 1. Clinical outcomes

Failure rates were significantly higher in the PRM group compared with the HT group (χ^2 , $p < 0.05$).

Table 1. Clinical outcomes of restorations after 24 months

Restoration Type	Successful n (%)	Failed n (%)	Total
PRM	12 (71%)	5 (29%)	17
Hall Technique	16 (91%)	2 (9%)	18
Total	28 (80%)	7 (20%)	35

Influence of Lesion Depth and Marginal Ridge Breakdown

Table 2 summarizes the distribution of major failures according to lesion characteristics. Shallow lesions without breakdown showed a very low incidence of major failure, with only 1 case (2%). In contrast, deep lesions with breakdown were associated with a substantially higher rate of major failures, accounting for 6 cases (31%). These results indicate that lesion depth and the presence of structural breakdown are important factors influencing the risk of major failure, with deep, broken-down lesions demonstrating a markedly greater failure rate compared to shallow lesions without breakdown.

Table 2. Major failure rates according to lesion characteristics

Lesion Type	Major Failures n (%)
Shallow lesions without breakdown	1 (2%)
Deep lesions with breakdown	6 (31%)

Deep lesions with marginal ridge breakdown exhibited a markedly higher proportion of major failures ($p < 0.001$).

Performance in Deep Lesions

Table 3 presents the restoration outcomes in deep carious lesions according to restoration type. The Hall Technique demonstrated a higher success rate, with 9 restorations (90%) remaining successful and only 1 failure (10%). In comparison, PRM restorations showed a lower success rate, with 6 cases (60%) classified as successful and 4 failures (40%). These findings suggest that, in the management of deep carious lesions, the Hall Technique may provide more favorable clinical outcomes than PRM, with a notably higher proportion of successful restorations and fewer failures.

Table 3. Restoration outcomes in deep carious lesions

Restoration Type	Success n (%)	Failure n (%)
PRM	6 (60%)	4 (40%)
Hall Technique	9 (90%)	(10%)

Among deep lesions, HT restorations demonstrated significantly superior longevity compared with PRM restorations.

Discussion

The present study adds to the growing body of evidence demonstrating the superior clinical performance of the Hall Technique (HT) compared with conventional plastic restorative materials (PRM) in the management of carious primary molars [12,13]. The significantly lower failure rate observed in the HT group is consistent with findings from multiple international studies conducted in both primary and secondary care environments. Large-scale randomized controlled trials from the United Kingdom [14] and Brazil [15] have reported survival rates for HT crowns exceeding 90% over periods of 3–5 years, substantially outperforming conventional restorations in comparable lesions. The present findings confirm that these advantages are reproducible within Romanian primary care settings, where clinical conditions may be less controlled than in academic centres.

Our findings indicate that, after 24 months, the Hall Technique was associated with more favourable clinical outcomes compared to PRM, showing a substantially higher proportion of successful restorations and a lower failure rate.

The markedly higher failure rate observed among PRM restorations, particularly in deep carious lesions, highlights well-recognized limitations associated with conventional restorative approaches in primary molars [8]- [13]. Achieving optimal moisture control in young children is often challenging, and the reduced enamel thickness and lower bonding reliability of primary teeth further compromise restoration longevity. In addition, polymerization shrinkage, wear, and marginal degradation are common causes of restoration failure over time. These limitations are amplified in lesions involving marginal ridge breakdown, where remaining tooth structure is insufficient to support long-term restoration integrity [14]- [16].

The strong association observed between marginal ridge breakdown and major failures is of particular clinical relevance. Marginal ridge integrity has been repeatedly identified in the literature as a critical prognostic indicator for restoration success in primary molars [10,14,15,16]. Lesions with compromised marginal ridges are more likely to progress rapidly, exhibit cuspal fracture, and result in pulpal involvement if managed with intracoronal restorations alone [14-16]. Our results suggest that in such cases, the Hall Technique offers a

more predictable and durable solution, significantly reducing the risk of pain, infection, and premature tooth loss.

In contrast, the Hall Technique circumvents many of these challenges by providing complete coronal coverage and sealing the carious lesion from the oral environment. The biological principle underlying HT—namely, caries arrest through isolation of cariogenic bacteria from their substrate—has been supported by microbiological and radiographic evidence [17]. Studies have demonstrated that sealed lesions beneath stainless-steel crowns show reduced bacterial viability and no increased risk of pulpal pathology when properly selected. The present study's findings, particularly the low incidence of major failures in the HT group, reinforce the biological soundness of this approach [17,18].

From a behavioural and practical perspective, the Hall Technique also offers important advantages in primary care dentistry. Its minimally invasive nature eliminates the need for local anaesthesia and rotary instrumentation, factors that are frequently associated with dental anxiety and uncooperative behaviour in children [9-12]. Previous studies have reported higher child and parent acceptability for HT compared with conventional restorations, as well as reduced chair time and operator stress. These benefits are particularly relevant in healthcare systems with limited access to paediatric dental specialists, where general practitioners must manage young patients efficiently and effectively [10]- [13].

The external validity of this study is strengthened by its exclusive implementation in primary care clinics, reflecting real-world clinical conditions. Unlike university-based trials, where operator expertise and resources may be optimized, the present study demonstrates that favourable outcomes with HT are achievable in routine dental practice. This supports broader integration of the Hall Technique into national clinical guidelines and undergraduate and continuing professional education curricula [9]- [14].

Nevertheless, several limitations should be acknowledged. The relatively small sample size may limit statistical power, and the non-randomized allocation introduces potential selection bias. Additionally, while the follow-up period of approximately 24 months is clinically meaningful, longer observation periods would be valuable to assess outcomes closer to the natural exfoliation of primary molars. Future multicentre randomized controlled trials with larger cohorts, cost-effectiveness analyses, and patient-reported outcome measures are warranted to further inform clinical decision-making.

Conclusions

Within the limitations of this controlled experimental study, the Hall Technique demonstrated significantly higher success rates and lower failure rates than conventional plastic restorative materials in primary molars over a 24-month follow-up period. The superiority of the Hall Technique was particularly evident in deep carious lesions with marginal ridge breakdown. These findings support the use of the Hall Technique as a reliable, minimally invasive, and clinically effective restorative option in primary dental care. Its broader implementation may improve long-term outcomes, reduce retreatment rates, and enhance the quality of paediatric oral healthcare in Romania and similar healthcare settings.

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ASSOCIATION BETWEEN EATING HABITS AND THE PREVALENCE OF DENTAL EROSIONS IN CHILDREN AGED 6 TO 12 YEARS – CROSS-SECTIONAL CLINICAL STUDY

Associate Professor, Ph.D. Sorana Maria BUCUR¹; Lecturer, Ph.D. Radu Mircea SIRETEANU CUCUI¹.

¹Department of Dentistry, Faculty of Medicine, Dimitrie Cantemir University of Târgu Mureş, 540545 Târgu Mureş, România

Corresponding author: Sorana Maria Bucur: bucursoranamaria@gmail.com

Abstract

Background: Dental erosion is a growing concern in paediatric oral health, with dietary habits—particularly the frequent consumption of acidic beverages—identified as a major etiological factor. This study aimed to evaluate the relationship between eating patterns and the prevalence of dental erosion among schoolchildren aged 6 to 12 years.

Methods: A cross-sectional clinical investigation was carried out among 36 children (18 boys and 18 girls) attending two primary schools in Braşov, Romania. The presence and severity of erosive tooth wear were assessed using the Basic Erosive Wear Examination (BEWE) index. Parents completed a structured questionnaire regarding their child's dietary practices, frequency of acidic food and drink intake, and oral hygiene behaviours. Associations between variables were examined using Chi-square and logistic regression analyses.

Results: Dental erosion was detected in 20 children (56%). Those consuming carbonated or fruit-based drinks more than twice weekly exhibited a significantly higher prevalence of erosive lesions (χ^2 [1, N = 36] = 5.84, P = 0.016). Regular milk intake was associated with a lower likelihood of erosion (OR = 0.41, 95% CI = 0.19–0.89). No significant associations were observed between erosion and toothbrushing frequency, BMI, or snack consumption (P > 0.05). **Conclusion:** More than half of the examined children exhibited signs of dental erosion, with frequent intake of acidic beverages as a key risk factor. Encouraging balanced dietary habits and milk consumption reduces dental erosion in school-aged children.

Keywords: dental erosion, eating habits, children, cross-sectional study, dietary behaviour, oral health

Introduction

Dental erosion is defined as the progressive and irreversible loss of dental hard tissues caused by chemical processes not involving bacterial activity [1]. Unlike dental caries, which is mediated by bacterial metabolism, dental erosion results from direct acid exposure and may occur even in individuals with good oral hygiene. In recent decades, dental erosion has emerged as a growing public health concern in paediatric dentistry, largely attributed to modern lifestyle changes, altered dietary behaviours, and the increasing availability and consumption of acidic foods and beverages [1,2].

Children are particularly susceptible to erosive tooth wear due to several biological and behavioural factors. Enamel in the primary and early permanent dentition is thinner and less

mineralized than in adults, rendering it more vulnerable to acid-induced demineralization [1–3]. Additionally, children often exhibit dietary patterns characterized by frequent snacking and the regular consumption of sweetened or flavoured beverages, which may prolong acid contact with dental surfaces and exacerbate erosive processes [2,3].

Among dietary determinants, the frequent intake of carbonated soft drinks, fruit juices, sports drinks, and other acidic beverages has been consistently identified as a major etiological factor in the development of dental erosion. These beverages commonly contain citric, phosphoric, or carbonic acids, which can significantly lower oral pH, reduce salivary buffering capacity, and promote enamel dissolution when consumed repeatedly or between meals [4–6]. The erosive potential of such drinks is influenced not only by their pH but also by their titratable acidity and frequency of consumption, making habitual intake particularly detrimental to dental hard tissues.

In contrast, certain dietary components may exert a protective effect against dental erosion. Milk and dairy products have been shown to contribute to enamel protection due to their calcium and phosphate content, as well as their ability to neutralize acids and enhance remineralization processes [7,8]. Encouraging the replacement of acidic beverages with milk or other non-acidic alternatives may therefore represent an important preventive strategy in paediatric oral health.

Despite the increasing recognition of dental erosion as a significant clinical issue, epidemiological data focusing on dietary risk factors in Romanian school-aged children remain scarce [9,10]. Most existing evidence originates from international studies, and differences in cultural dietary practices, socioeconomic factors, and oral health education may limit the direct applicability of these findings to the Romanian population.

A clearer understanding of the relationship between eating patterns and erosive tooth wear in Romanian children is essential for the development of targeted preventive and educational programs. Therefore, this study aimed to evaluate the association between dietary habits and the prevalence of dental erosion among children aged 6 to 12 years attending primary schools in Târgu Mureş, Romania.

Materials and Methods

Study Design and Population

This cross-sectional clinical study was conducted among 36 children (18 boys and 18 girls) aged between 6 and 12 years. Participants were recruited from two primary schools in Târgu Mureş, Romania. Children were included if they were in good general health and had no systemic conditions known to affect enamel integrity.

Exclusion criteria included the presence of developmental enamel defects, orthodontic appliances, systemic diseases associated with enamel erosion, or the use of medications with known erosive potential.

Clinical Examination

Dental erosion was assessed by a single calibrated examiner using the ***Basic Erosive Wear Examination (BEWE) index***. All teeth were examined, and the highest BEWE score recorded per sextant. Based on cumulative BEWE scores, children were classified as having or not having erosive tooth wear.

Questionnaire Data

Parents or legal guardians completed a structured questionnaire designed to collect information on:

- Frequency of consumption of acidic foods and beverages (carbonated drinks, fruit juices)
- Milk and dairy intake
- Snacking habits
- Oral hygiene practices, including toothbrushing frequency
- Body mass index (BMI), calculated using reported height and weight

Dietary frequency was categorized as ≤ 2 times per week or > 2 times per week for statistical analysis.

Statistical Analysis

Data were analyzed using statistical software. Descriptive statistics were calculated for all variables. Associations between dental erosion and categorical variables were assessed using Chi-square tests. Logistic regression analysis was performed to evaluate the strength of associations and calculate odds ratios (OR) with 95% confidence intervals (CI). Statistical significance was set at $P < 0.05$.

Results

Participant Characteristics

A total of 36 children aged 6–12 years were included in the study, comprising 18 boys (50%) and 18 girls (50%). The mean age of the participants was 9.1 ± 1.8 years. No significant differences were observed between boys and girls with respect to age, BMI category, or oral hygiene habits ($P > 0.05$).

Prevalence and Severity of Dental Erosion

Dental erosion, as assessed using the BEWE index, was identified in **20 children (56%)**, while 16 children (44%) showed no clinical signs of erosive tooth wear. Most affected children exhibited **low to moderate BEWE scores**, indicating early-stage erosive lesions rather than advanced tissue loss (Table 1).

Table 1. Prevalence of dental erosion in the study population

BEWE status	Number of children (n)	Percentage (%)
No erosion	16	44.4
Dental erosion present	20	55.6
Total	36	100

Erosive lesions were predominantly observed on the palatal surfaces of maxillary anterior teeth and on the occlusal surfaces of posterior teeth, consistent with patterns associated with dietary acid exposure.

Dietary Habits and Dental Erosion

Children who consumed carbonated beverages or fruit-based drinks more than twice per week showed a significantly higher prevalence of dental erosion compared with those who consumed such drinks less frequently (Table 2).

Table 2. Association between acidic beverage consumption and dental erosion

Acidic beverage intake	Dental erosion present n (%)	No erosion n (%)	P-value
≤ 2 times/week	6 (30.0)	10 (62.5)	
> 2 times/week	14 (70.0)	6 (37.5)	0.016

Figure 1 illustrates the relationship between acidic beverage consumption and the presence of dental erosion. Children who consumed carbonated or fruit-based drinks more than twice per week showed a markedly higher number of erosive lesions compared with those who consumed such beverages less frequently. In contrast, among children with acidic drink intake limited to two times per week or less, the majority exhibited no signs of dental erosion.

This association was statistically significant (χ^2 [1, N = 36] = 5.84, p = 0.016), confirming frequent acidic beverage intake as a major risk factor for erosive tooth wear.

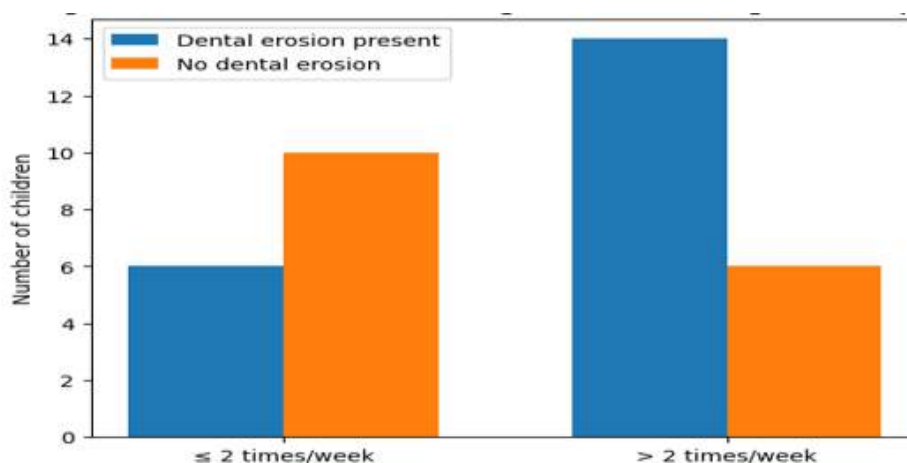


Figure 1. Dental erosion and acidic beverage consumption.

Grouped bar chart showing the number of children with and without dental erosion according to the frequency of acidic beverage intake (≤2 times/week vs >2 times/week).

Chi-square analysis confirmed a statistically significant association between frequent acidic beverage consumption and the presence of erosive tooth wear (χ^2 [1, N = 36] = 5.84).

Protective Dietary Factors

Regular milk consumption was inversely associated with dental erosion. Children who consumed milk daily exhibited a significantly lower prevalence of erosive lesions (Table 3).

Table 3. Logistic regression analysis of dietary factors associated with dental erosion

Variable	Odds Ratio (OR)	95% CI	P-value
Frequent acidic drink intake (>2/week)	2.74	1.21–6.18	0.018
Regular milk consumption	0.41	0.19–0.89	0.024
Frequent snacking	1.12	0.53–2.36	0.76

Children who regularly consumed milk had a **59% reduced odds of dental erosion**, highlighting a potential protective role of dairy intake.

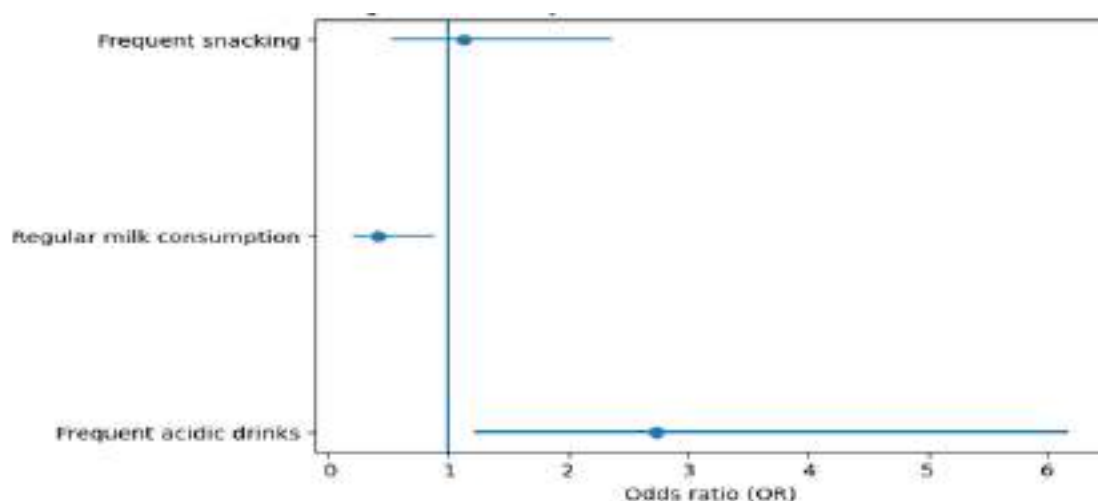


Figure 2. Dietary factors associated with dental erosion. Forest plot presenting odds ratios (OR) with 95% confidence intervals for dietary variables associated with dental erosion. The vertical reference line at OR = 1 indicates no association.

Figure 2 presents the results of the logistic regression analysis evaluating dietary factors associated with dental erosion. Frequent consumption of acidic beverages was significantly associated with an increased risk of erosion (OR = 2.74; 95% CI: 1.21–6.18). In contrast, regular milk consumption was associated with a significantly reduced likelihood of erosive tooth wear (OR = 0.41; 95% CI: 0.19–0.89), suggesting a protective effect. Frequent snacking did not show a significant association with dental erosion, as its confidence interval crossed the null value (OR = 1.12; 95% CI: 0.53–2.36).

Other Factors

No statistically significant associations were identified between dental erosion and:

- Toothbrushing frequency;
- Body mass index (BMI);
- Snack consumption frequency.

These variables were therefore not retained as significant predictors in the final regression model ($P > 0.05$).

Discussion

The present cross-sectional study demonstrated a **high prevalence of dental erosion (56%)** among school-aged children, emphasizing that erosive tooth wear represents a relevant and under-recognized oral health issue in pediatric populations. This prevalence aligns with international data suggesting a rising incidence of dental erosion in children due to evolving dietary behaviors [11,12].

Frequent consumption of acidic beverages emerged as the strongest risk factor for dental erosion [5,13]. Children who consumed carbonated drinks or fruit juices more than twice weekly were nearly three times more likely to exhibit erosive lesions. These findings reinforce the well-established role of dietary acids in enamel demineralization. The low pH and high titratable acidity of such beverages can prolong enamel exposure to erosive conditions, particularly when consumed between meals [5,14,15].

A key finding of this study was the ***protective association between regular milk consumption and reduced erosion risk***. Milk's buffering capacity, along with its calcium and phosphate content, likely contributes to enamel remineralization and acid neutralization [6-8]. This supports previous evidence suggesting that dairy products may mitigate the harmful effects of acidic diets and highlights milk as a valuable preventive dietary component in children [16].

Interestingly, no association was observed between dental erosion and toothbrushing frequency. This may reflect the fact that erosion is primarily a chemically driven process rather than a plaque-mediated one [17]. Moreover, brushing immediately after acid exposure may even exacerbate enamel loss, underscoring the proper oral hygiene timing rather than frequency alone [17,18].

The lack of association between BMI and erosion suggests that erosive risk is not necessarily related to overall dietary quantity or nutritional status but rather to ***specific dietary patterns***, particularly acid exposure [19,20]. Similarly, snack frequency alone did not appear to increase erosion risk unless snacks included acidic components [5,21,22].

This study has several limitations. The relatively small sample size limits external validity, and the cross-sectional design prevents conclusions regarding causality. Dietary data were collected through parental questionnaires, which may be subject to recall bias. Nevertheless, the use of the BEWE index and standardized clinical examination strengthens the reliability of the findings.

Future research should include larger, multicentred samples and longitudinal designs to assess better erosion progression and the long-term impact of dietary modifications. Educational interventions targeting parents and children could also be evaluated for their effectiveness in reducing erosive tooth wear.

Conclusions

Dental erosion was highly prevalent among the examined school-aged children. Frequent intake of acidic beverages significantly increased the risk of erosive tooth wear, while regular milk consumption appeared to have a protective effect. Preventive strategies should focus on dietary counselling, reduction of acidic drink consumption, and promotion of healthier alternatives to protect enamel integrity in children.

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REDUCTION OF ETHANOL ELIMINATION RATE DUE TO INTERACTIONS PHARMACOKINETICS WITH CERTAIN DRUGS

Associate Professor, Ph.D. Doina MOALEȘ; Associate Professor, Ph.D. Carmen GÂLEA¹; Lecturer, Ph.D. Radu Mircea SIRETEANU CUCUI 1; Associate Professor, Ph.D. Sorana Maria BUCUR¹

¹Department of Dentistry, Faculty of Medicine, Dimitrie Cantemir University of Târgu Mureș, 540545 Târgu Mureș, România

Corresponding - Radu Sireteanu Cucui: medidentes@yahoo.com, Sorana Maria Bucur: bucursoranamaria@gmail.com

Abstract

Pharmacokinetic and pharmacodynamic interactions of alcohol are a serious problem for both doctors and patients. To minimize these effects, it is necessary to achieve better compliance of patients to treatment. For this reason, the patient should be explained the influence of alcohol on the absorption, distribution, and elimination of the drug and its synergistic effects with certain groups of drugs (sedato-hypnotics, sedato, antidepressants, neuroleptics, antiepileptics, antihistamines, analgesics). Another important aspect is the increase in liver and kidney toxicity of some groups of drugs in combination with alcohol. Excessive alcohol consumption can have numerous adverse effects on general health and, implicitly, on oral health. It is important to note that moderate alcohol consumption is generally not associated with the same risks as excessive consumption. However, limiting alcohol consumption and maintaining proper oral hygiene are essential for oral health.

Keywords: alcohol, drug interactions, alcohol pharmacokinetics, intoxication, alcohol dehydrogenase

1. Introduction

Alcohol consumption can be considered from many perspectives, the oldest drug of mankind, due to its euphorizing and disinhibiting effect, especially in the first phase of alcoholic intoxication [1,2]. Imbibition alcoholic presents itself as an uncurbed with a slope ascending presenting the phase of deaccumulation, plateau, and a pending presenting the phase of elimination. This course of alcohol concentration in the body is related to the amount of alcohol consumed, about weight, height, and sex, and the presence or absence of food in the stomach. [1]- [5].

An important factor is the rate of oxidation of alcohol which can be influenced by both the enzymatic baggage of the consumer and certain medicinal active substances present in the body or administered during alcohol consumption. They work through various mechanisms in favor of increasing blood alcohol concentration or increasing the rate of alcohol metabolism, which is difficult to prove in toxicological practice. [1,3,4,5].

2. Material and Method

Thus, in the case of driving a car on public roads in the background of drinking alcoholic beverages, a V.E. man of 28 years old, is stopped in traffic by the police, and when testing with the ethylates at 19.10 it has a value of 0.48‰ in the exhaled air. According to the road legislation, the values on the ethylotest apparatus over 40‰, require the collection of biological samples, to determine the concentration of ethyl alcohol in the blood. The man was taken to the hospital unit where the first blood sample was collected at 19.35, the second one being collected after an hour, respectively at 20.35.

The samples were taken to the laboratory where they were toxicologically analyzed to determine the concentration of ethyl alcohol in the blood at the time of collection.

The samples were processed for analysis by ultrasonic homogenization using the UP100H ultrasonic Processor with cycle 0,50 /80 Amplitude. The internal standard of Tert Butanol 0.15mL‰, was prepared with an analytical balance AND HR200 A&D Instrument LTD and automatic pipette Eppendorf.

Thus, the processed samples are analyzed using the official method, with a Clarus 690 gas chromatograph with capillary injector (CAP) Perkin Elmer, equipped with two chromatographic columns, respectively, Elite BAC 1 Advantage chromatographic column: 30m x 0.32mm x 1.8µm and Elite BAC Chromatographic Column 2 Advantage: 30m x 0.32mm x 0.6µm and two flame ionization detectors (FID), injection Extraction System Turbomatrix Headspace 40. The working parameters of the device are Temperature: 200°C; Rate Splitting 5: 1; two columns; Work temperature: 450°C, isothermal; carrier gas pressure: 15 psi (debit-4.02 mL/min, etc, average column speed-57.5 cm/sec); Detectors: Temperature - 220°C; Mobile phase - Hydrogen dioxide-30 ml/min; Airflow - 450 ml/min. The selectivity of the method was tested by analyzing a multicomponent mixture consisting of methanol, ethanol, isopropanol, and acetone, the results were evaluated using the criteria for acceptance of the specificity test, and the results were evaluated, thus, Ethanol appeared at the same time as retention in positive samples and verification solutions. The linearity of the method was evaluated by testing several solutions with known theoretical concentrations, obtaining the response factor R2 on channel A - 0.999562, and channel B - 0.999370. The detection limit of the device is set at LOD-0.0125‰ and the limit of quantification LOQ - 0.0333. Reproducibility has also been tested by LGC Axio Proficiency Testing INC.

3. Results and Discussion

The toxicological analysis resulted in the following values: at the first sample collected at 19.35 the alcohol value was 1.06‰, respectively, and in the second sample harvested after an hour at 20.35, the alcohol value was 0.84‰. (fig.1)

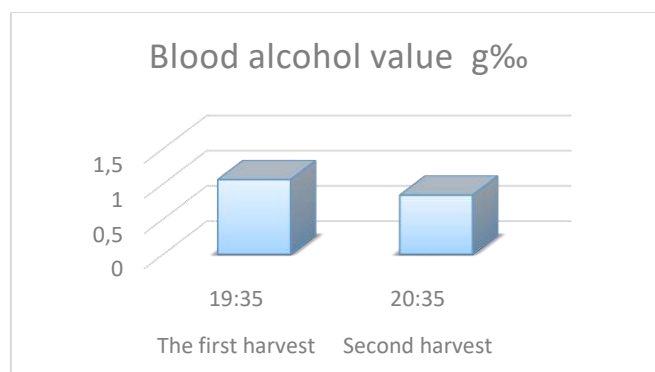


Figure 1. Blood alcohol value g‰

After consulting the accompanying files of the evidence containing the data of the subject, the clinical examination, and its statements regarding the consumption of alcohol, it is found that he is 28 years old, the height of 165 cm, and weight 82 kg.

Table 1.

Medication used daily	Dose/day/82kg/165cm	cp/day
methylprednisolone	16 mg	1cp
metronidazole	250 mg	3cp
desloratadină	5 mg	1cp
aminofenacetină	500 mg	3cp
ibuprofen	400 mg	2cp
ranitidine	150mg	3cp
oxymetazoline hydrochloride	0.5 mg/ml	3-4 down

He also stated that he consumed 400 mL of Whisky in the interval 8.30 - 10.00 without food consumption, noting that he ate nothing throughout the day. From the clinical examination results the patient suffers from allergic rhinitis and permanently uses the following active substances: 16 mg (1 hp/day) methylprednisolone, metronidazole 250 mg (3 hp/day), desloratadine 5 mg (1 hp/day), aminofenacetin 500 mg (3 hp/day), ibuprofen 400 mg (2 hp/day), ranitidine 150 mg (3 hp/day), oxymethazoline hydrochloride 0.5 mg/ml nasal spray (3-4 puffs/day). (tab.nr.1).

Table 2.

N r.	Active substance	Pharmacological group	Pharmacological action	Interaction with alcohol
1.	Methylprednisolone	steroidal anti-inflammatories (A.I.S)	anti-inflammatory antiallergic * immunosuppressive	✓ a synergistic effect has been reported in association with alcohol and disulfiram-like reactions when methylprednisolone is associated with metronidazole [6]
2.	Metronidazole	chemotherapy	anti-infectious used in anaerobic bacterial	✓ in combination with alcohol metronidazole may cause disulfiram reactions. A 72-hour interval is

N r.	Active substance	Pharmacological group	Pharmacological action	Interaction with alcohol
			infections (* in the gastrointestinal tract)	required between admin. de metronidazole and alcohol consumption. [7]
3.	Desloratadine	antihistamine	relieves symptoms associated with allergic rhinitis*	⚡ No adverse reactions have been reported with the combination of desloratadine and alcohol except for potentiation of the effect of desloratadine [8,9]
4.	Acetaminophen	analgesic	analgesic antipretic nasal decongestant *	⚡ administered to alcoholics acetaminophen increases the risk of liver damage [10]
5.	Ibuprofen	non-steroidal anti-inflammatory (A.I.N.S)	anti-inflammatory* antipretics analgesic antiaggregant plaquetaire	✓ alcohol-associated ibuprofen increases the hepatotoxicity of ethanol by increasing the production of reactive oxygen species (ROS) [11] ✓ increases the risk of gastric bleeding
6.	Ranitidine	histamine H2 blocker	antiulcer	✓ stimulates gastric evacuation of ethanol with increased ethanol concentration in the blood and inhibits ADH activity in the stomach by reducing first pass metabolism through the stomach and increasing alcohol in the blood
7.	Oxymetazoline hydrochloride	Sympathomimetic	nasal congestion treatmentallergic rhinitis* cold and flu infections resp.	⚡ no interactions of ethanol with this have been reported

The values obtained in this case fall within the specifications of the literature, respectively, the concentration value of ethyl alcohol in the blood is $\pm$ double the concentration value in the exhaled air, absorption phase assuming a steady increase in alcohol time to maximum within 30 minutes if no food in the stomach and up to 1½ - 3 hours when drink alcoholic beverages with a full stomach preponderantly protein foods - fatty [1,2,12,13].

According to the subject's statements regarding the time of consumption and the amount of alcohol consumed, the maximum concentration of alcohol in the blood should have been found around 11 o'clock, the value that can be calculated according to the amount of alcohol consumed, about weight and Widmark factor or diffusion coefficient. The Widmark factor represents the practical ratio of tissues with water content to the fat tissues of the human body and is correlated with the body mass index BMI – Body Mass Index.

This factor is different in women than men but, depends to the same extent and age, because the amount of fat tends to increase with age especially in men, to the detriment of mail. Thus, it follows that another important factor of this report is the body constitution of the subject which is independent of height, for example, two persons of the same sex, the same height and weight, the same, they may have a different diffusion coefficient due to the preponderant presence of muscle mass for which alcohol has greater affinity, or overweight, of adipose tissue. After numerous statistical measurements, it was considered that the diffusion factor Widmark

for men is 0.68 with variations (0.51÷0.85) and for women 0.55 with variations (0.44÷0.66) [1,2,12,13].

In this case, theoretically, according to gender, weight/height ratio, BMI is 0.49 but, following the investigations, it was found that the subject, although only 165 and weighing 82 kg, had a body constitution with well-proportioned muscle mass, thus, it recommends the use in calculating the theoretical concentration of the Widmark Factor value of 0.68, thus leading to a theoretical alcoholic concentration of $2.22\% \pm 5\%$ compared to the amount of alcohol ingested. This concentration can be calculated by the formula:

$$C\text{ ‰} = A : (r \times G)$$

Where A is the amount of pure alcohol ingested, r – is the Widmark Factor, Weight of the subject. [1,2,12,13].

Elimination rate according to Widmark: 0.15 (0.10÷0.24) g/l/h is obtained from the difference in the ethanol concentration values from the first sample with the value from the second sample. This is why it is recommended to take two blood samples at an interval of one hour.

In this case, resulting in 0.22‰. Performing a theoretical calculation according to the elimination rate about the statements of the subject, at 19.35 hours after 8 ½ hours from the maximum absorption time, at the time of absorption, it was supposed to have an approximate blood alcohol concentration of $0.35\text{‰} \pm 5\%$. Compared to the real value obtained at the first sample of 1.06‰ and the theoretical value of 0.35‰, it is attempted to identify the factors that caused the elimination rate to slow down over the 8 ½ hours after alcohol consumption. In toxicological practice, there have been rare cases where it is necessary to discern between a classic alcoholic intoxication and one influenced by extrinsic factors such as medicinal substances. The interactions of ethanol with medicinal substances are of a pharmacokinetic and pharmacodynamic nature. Changes in the absorption, distribution, metabolism, and elimination of alcohol influence both the pharmacokinetics and pharmacological effects of drugs. Alcohol can reach the bloodstream and then the brain in a relatively short five-second interval, in the stomach the amount of alcohol will be small and has the potential to be relieved through the sweat glands breathing. The highest amount of alcohol is metabolized in the gut andubtire, pancreas, and liver for metabolism in 90%. Detection of alcohol in urine can be done up to 12 hours. (fig 2.)



Figure 2. Alciool times in the body

It is known that ethanol is metabolized by three pathways, namely the catalase pathway that metabolizes about 2% %, the microsomal pathway that can metabolize up to 20 % from the alcohol ingested by cytochrome P450 and CYP2E1, in particular when the blood ethanol concentration exceeds 1 % as found in the subject of the discussion. CYP2E1 directly participates in the oxidation of chemicals with small organic molecules such as ethanol, acetone and pyrazole; endogenous compounds, including, but it also has an affinity for several medicinal active substances such as salicylates, anti-tuberculosis, general anesthetics, analgesics-antipyretics type acetoaminophen, methylxanthines (theophylline), hypnotics (zopiclone, eszopiclon), central myorelaxants (chlorzoxazone), antitumor (cisplatin) and several toxic chemicals (carbon tetrachloride, chloroform, nitrosamines, benzene, acrylamide, dimethylformamide) [4,14,15,16]. Having such an affinity, several reactive substances create a competitive base on CYP2E1 until exhaustion [5,14-19].

The ADH pathway is the major metabolic pathway for ethanol via Alcoholdehydrogenase which corresponds to the first passage of mucosa gastric mucosal metabolism in the metabolism as well as the secondary metabolism by the intermediate ADH enzymes in the liver. Alcohol dehydrogenase (ADH) is a zinc-dependent enzyme with numerous isoenzymes, which has a wide specificity in the oxidation of primary or secondary alcohols, as well as for several substances present in various drugs. The highest amounts of ADH are distinguished, in the stomach, liver, gastrointestinal tract, kidneys, and nasal mucosa [1-3].

During this process, the stomach through ADH and its isoenzymes can metabolize significant amounts of ethanol, achieving the so-called first-pass metabolism, the important thing is that ADH contacts ethanol as much as possible. As a result of accelerated gastric emptying that causes gastric ADH to have short-term contact with ethanol, this first metabolic passage is not present in the fast and is diminished in alcoholics. The presence of food in the stomach, including high-fat, carbohydrate, or protein meals, delays gastric emptying, so ADH will have a longer time of contact with ethanol, manifested by reduced alcohol absorption and the resultant metabolites [5,20,21,22].

Irritations or erosions in the gastric mucosa, bleeding, and paralysis of the smooth muscles of the stomach, will consequently reduce the metabolism of the first passage. Gastric ADH activity in addition to the ADH isoenzyme expression model is affected by various factors, such as gender, age, genetic pattern, ingested ethanol concentration, gastric morphology, etc, the presence of *Helicobacter pylori* and last but not least, the presence of medicinal substances. Decreased activity of ADH in alcoholics, especially in alcoholic women, also involves the reduction of the metabolism of the first passage, resulting in increased sensitivity to alcohol and higher levels of ethanol in the blood in women than in men after an equivalent oral dose [1,2,4,12,21,22].

From the point of view of the type of drink, fermented alcoholic beverages containing a high amount of sugar delay gastric emptying by high osmotic pressure [20-22] compared to spirits with high ethanol concentrations leading to faster gastric emptying default to lower contact with ADH.

Apart from influencing the evacuation of the stomach, interactions between alcohol and medicinal products at the level of absorption may, on the one hand, cause changes in the solubility of pharmaceutical preparations by ethanol, thereby altering the time and extent of their absorption, on the other hand, some pharmaceutical substances may interfere with the intensity of alcohol metabolism in the stomach by stimulating gastric emptying or by the competitive effect of medicinal products on the activity of gastric DHA and CYP2E1 [4,8,20].

Thus, several drugs increase alcohol exposure to gastric ADH, reducing the evacuation of ethanol in the small intestine with reduced levels of alcohol in the blood and an increase in the rate of metabolites [4,15,23]. In antagonism, medicinal products such as cimetidine, ranitidine, histaminergic H₂ blockers, and metoclopramide have a stimulating effect on gastric emptying with increased blood ethanol concentration, particularly by decreasing contact with gastric ADH, [4,23,24,25].

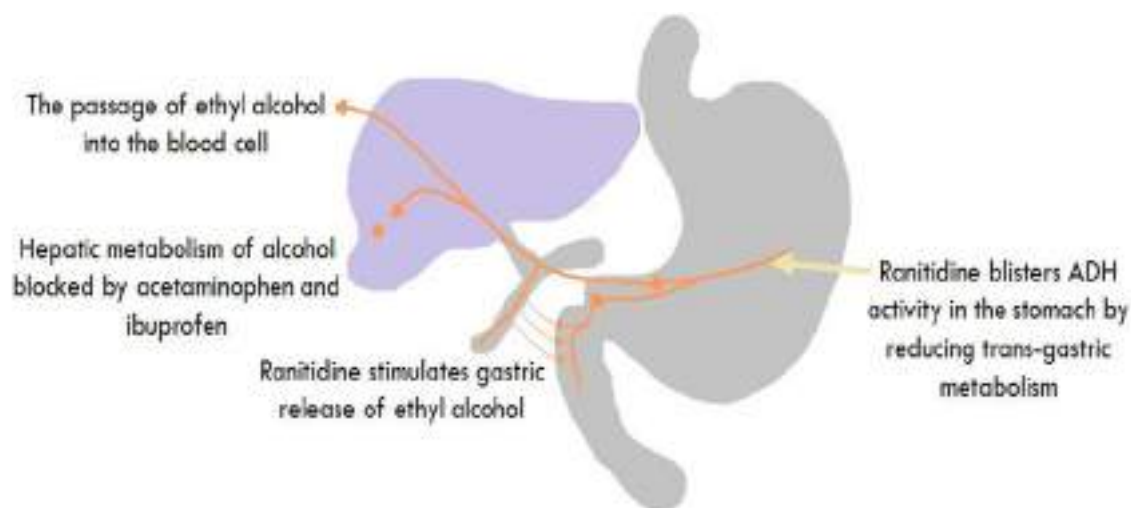


Figure 3. Alcohol ingested through the mouth is processed by the body through various metabolic processes, one of which takes place in the stomach. Once alcohol reaches the stomach, a portion of it is broken down by the enzyme alcohol dehydrogenase (ADH).

Of H₂ histamine blockers the most pronounced effect is cimetidine and ranitidine, nizatidine has an intermediate effect and famotidine does not seem to influence gastric ADH levels. [8]. H₂-histamine blockers, at a dose of 0.15 g/kg of alcohol, may cause a slight increase in blood alcohol levels, and at a dose of 0.3 g/kg and more no significant interactions were found between anti-secretory and ethanol. It was estimated that the increase in the absorption of ethanol at low, repeated doses of alcohol would be due to the acceleration of gastric emptying by these drugs.

The increased ethanol concentration in the blood is also supported by the fact that histaminergic H₂ blockers (cimetidine, ranitidine, etc.), acetylsalicylic acid, acetaminophen, and, have an inhibitory effect on the activity of ADH in the stomach to a varying extent depending on the gastric metabolism of the first passage, causing a slight increase in blood alcohol concentrations especially in young nonalcoholic and non-Asian men [4,12,15,16]. Also, monodose consumption involves higher blood alcohol levels if the same amount of ethanol is ingested in smaller doses [4,20,23].

Excessive alcohol consumption can have numerous adverse effects on oral health. Alcohol can irritate tissues in the oral cavity, including gums and oral mucosa, increasing the risk of inflammation, bleeding, and other problems. Alcohol has a dehydrating effect, which can contribute to dry mouth. Saliva is essential for oral hygiene, as it helps to wash away food debris and neutralize acid [26-28].

Alcohol contains sugar and acid, and excessive consumption can contribute to the development of tooth decay. Excessive alcohol consumption may increase the risk of gum

disease, such as gingivitis or periodontitis. This is partly due to the negative impact on the immune system and the body's ability to fight infections. [27-31].

Excessive and prolonged consumption of alcohol is associated with an increased risk of developing oral cancer. Alcohol can interact with medications prescribed for various dental conditions or oral cavities, reducing the effectiveness of treatment and generating potential complications. [27-30].

Excessive alcohol consumption can lead to behaviors at high risk of oral trauma, such as falls or accidents that can affect teeth and oral structures. [26-31].

4. Conclusions

The combination of ethanol with certain drugs causes a slowdown in the elimination rate, in our case, particularly supported by ranitidine, which contributes to reaching an alkalemia above the legal limit allowed, so the legal classification of the subject can be criminal.

This could have been avoided if the subject had been aware of the potential risks of the drug-drug combination and drug-alcohol interaction.

In addition to prescription medicines, for which patients are warned about possible pharmacokinetic or pharmacodynamic interactions (acetaminophen, ibuprofen, acetylsalicylic acid, or oTCs, etc.) having the false impression that these drugs could not cause serious problems.

From a pharmacodynamic point of view, ethanol may enhance the sedative effect of antihistamines (especially non-selective ones), the ulcerative effect of non-steroidal anti-inflammatory drugs, and the hepatotoxic effect of acetaminophen.

Synergistic action was also observed in herbal medicinal products with sedative action (chamomile, echinacea, and valerian) associated with alcohol.

Excessive alcohol consumption can have numerous adverse effects on general health and, implicitly, on oral health. It is important to note that moderate alcohol consumption is generally not associated with the same risks as excessive consumption. However, limiting alcohol consumption and maintaining proper oral hygiene are essential for overall oral health.

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THE ROLE OF METABOLIC DISORDERS IN THE ONSET AND PROGRESSION OF PERI-IMPLANT INFLAMMATION

University Teaching Assistant, Ph.D. Student Alexandra Camelia POGĂCIAN-MAIER¹; University Teaching Assistant, Ph.D. Student Mioara DÂRNEA²; Lecturer, Ph.D. Dana BACIU; University Teaching Assistant³, Ph.D. Student Cristian COJOCARIU⁴; University Teaching Assistant, Ph.D. Student Dorin Ioan COCOȘ⁴

¹Doctoral School, University of Medicine and Pharmacy "Iuliu Hatieganu" Cluj-Napoca, 400347 Cluj-Napoca, Romania;

²Department of Implantology, Removable Protheses, Dental Protheses Technology, "Grigore T. Popa" University of Medicine and Pharmacy, 16 Universității Street, 700115 Iași, Romania;

³Department of Dentistry, Faculty of Medicine, Dimitrie Cantemir University of Târgu Mureș, 540545 Târgu Mureș, România;

⁴Faculty of Dental Medicine, "Dunărea de Jos" University, 800008 Galați, Romania

Author correspondent: Dorin Ioan COCOȘ: cdorin1123@gmail.com

Abstract

Metabolic disorders such as diabetes mellitus, obesity, and dyslipidaemia have emerged as key systemic factors influencing peri-implant health. This review explores the mechanisms by which metabolic imbalance contributes to the onset and progression of peri-implant inflammation. Clinical and experimental studies reveal that hyperglycaemia, insulin resistance, and altered lipid metabolism disrupt host immune responses, enhance oxidative stress, and impair soft and hard tissue healing around dental implants. These systemic alterations lead to an increased production of pro-inflammatory cytokines, including TNF- α , IL-1 β , and IL-6, which promote peri-implant tissue breakdown and bone resorption. Diabetic and obese patients exhibit a higher prevalence and severity of peri-implant mucositis and peri-implantitis compared with systemically healthy individuals. Moreover, impaired microcirculation and collagen metabolism delay wound healing and compromise osseointegration. Effective management requires an interdisciplinary approach integrating metabolic control, personalized maintenance protocols, and regular monitoring of peri-implant parameters. Future research should focus on molecular pathways linking systemic inflammation and implant-related tissue destruction to develop targeted preventive and therapeutic strategies.

Keywords: peri-implantitis, metabolic disorders, diabetes mellitus, obesity, inflammation, osseointegration

1. Peri-implant Inflammation: Epidemiology and Clinical Burden

Peri-implant inflammation represents one of the most significant biological complications associated with implant-supported oral rehabilitation, with direct implications for long-term implant survival and patient quality of life. Epidemiological data accumulated over the past two decades indicate that peri-implant mucositis and peri-implantitis are highly prevalent conditions, with wide variability depending on diagnostic criteria, follow-up duration, and patient-related risk profiles [1]. Early observational studies highlighted that peri-implant inflammatory lesions are not rare findings in routine clinical practice, even in populations

treated within university-based settings and presumed to benefit from standardized therapeutic protocols [2].

Cross-sectional investigations consistently report a substantial proportion of implants exhibiting signs of soft tissue inflammation and marginal bone loss, particularly in patients not enrolled in structured supportive periodontal or peri-implant maintenance programs [3]. These findings underscore the critical role of long-term professional monitoring in preserving peri-implant tissue health. Furthermore, multicentre analyses have demonstrated that peri-implantitis prevalence increases with time in function, suggesting a cumulative biological burden rather than an isolated postoperative complication [4].

From a prosthetic standpoint, fixed implant-supported rehabilitations are not exempt from inflammatory complications. Studies evaluating patients with implant-supported fixed prostheses revealed notable rates of peri-implantitis, emphasizing that prosthetic stability alone does not guarantee biological success [5]. Long-term follow-up data extending up to 14 years further confirmed the persistence and progression of peri-implant lesions, reinforcing the concept that peri-implant inflammation is a chronic condition with potential for gradual tissue breakdown if left inadequately managed [6].

Risk factor analysis has provided valuable insight into patient- and implant-level determinants of peri-implant disease. Longitudinal studies identified associations between peri-implant lesions and factors such as previous periodontal disease, inadequate plaque control, and irregular maintenance attendance [7]. These observations support the biological continuity between periodontal and peri-implant inflammatory processes and suggest that implants placed in susceptible hosts may follow similar pathogenic trajectories.

At the molecular level, genetic susceptibility has also been explored as a potential contributor to peri-implant inflammation. Investigations into interleukin-6 gene promoter polymorphisms revealed possible shared genetic risk factors between chronic periodontitis and peri-implant disease, highlighting the multifactorial and host-modulated nature of peri-implant tissue breakdown [8]. Such findings further complicate the epidemiological landscape by introducing individual variability beyond clinical and behavioural determinants.

Radiographic evaluation of marginal bone loss has been instrumental in defining the burden of peri-implant disease. Cross-sectional analyses demonstrated that marginal bone loss is a frequent finding among implant patients, even in the absence of overt clinical symptoms, emphasizing the silent progression of peri-implant pathology in certain cases [9]. Soft tissue characteristics also play a decisive role; the lack of keratinized mucosa has been repeatedly associated with poorer peri-implant tissue health, increased plaque accumulation, and higher inflammatory indices [10].

Periodontal status remains a central determinant of peri-implant outcomes. Clinical studies have shown that patients with compromised periodontal conditions exhibit a higher susceptibility to peri-implantitis, particularly when residual periodontal inflammation persists at the time of implant placement or during follow-up [11]. Long-term observational data corroborate these findings, demonstrating that peri-implant mucositis and peri-implantitis prevalence increases after extended loading periods, even beyond seven years of functional use [12].

The type of prosthetic rehabilitation and loading protocol also influences peri-implant tissue behaviour. Investigations into immediately loaded, full-arch implant-supported prostheses revealed that peri-implant tissue health may deteriorate over time, with progressive bone resorption observed in a subset of patients despite initially favourable outcomes [13]. Importantly, patient-reported satisfaction does not always correlate with biological stability, as

demonstrated by studies highlighting a discrepancy between subjective comfort and objective peri-implant complication rates in individuals lacking structured maintenance care [14].

The presence and quality of keratinized mucosa have been further validated as protective factors, particularly in patients with erratic maintenance compliance. Adequate keratinized tissue appears to mitigate inflammatory changes and facilitate plaque control, thereby reducing peri-implant disease risk [15]. Epidemiological data from diverse populations, including Japanese cohorts, confirm that peri-implant diseases are globally prevalent and influenced by both systemic and local risk indicators [16].

Preventive maintenance emerges as a decisive modifier of disease incidence. Longitudinal follow-up studies demonstrated significantly lower rates of peri-implant disease in patients adhering to regular preventive programs compared to those without systematic maintenance [17]. Similarly, edentulous patients rehabilitated with implant-retained overdentures exhibited cumulative incidences of peri-implant mucositis and peri-implantitis over a 10-year period, reinforcing the need for lifelong monitoring irrespective of prosthetic design [18].

Finally, long-term prospective cohort studies comparing patients with and without a history of chronic periodontitis confirmed that prior periodontal disease adversely affects implant prognosis, increasing the likelihood of peri-implant inflammation and bone loss over a 10-year follow-up [19]. Collectively, these data position peri-implant inflammation as a prevalent, multifactorial, and clinically significant condition, necessitating comprehensive risk assessment and sustained preventive strategies from the earliest stages of implant therapy.



Figure 1. Peri-implant inflammatory lesions associated with advanced peri-implantitis

Figure 1, Clinical close-up illustrating severe peri-implant inflammation characterized by erythematous and oedematous peri-implant mucosa, plaque and calculus accumulation on exposed implant threads, and purulent exudate, consistent with advanced peri-implantitis and ongoing peri-implant tissue breakdown.

2. Metabolic Disorders as Systemic Risk Modifiers in Peri-implant Disease

Peri-implant disease is increasingly recognized as the result of a complex interaction between local microbial challenges and systemic host-related factors. While plaque accumulation and inadequate maintenance remain primary etiological elements, systemic conditions that modulate inflammatory burden and immune competence can significantly influence peri-implant tissue responses. Metabolic disorders, particularly diabetes mellitus, obesity, and dyslipidemia, contribute to a state of chronic low-grade inflammation that may exacerbate peri-implant tissue breakdown and alter disease susceptibility [1,5].

Epidemiological studies evaluating peri-implantitis prevalence consistently identify patient-related risk indicators beyond local factors, emphasizing the role of systemic health status in disease expression [2,4]. Although many investigations primarily focused on periodontal history and maintenance compliance, these variables frequently coexist with metabolic imbalances, which may act as amplifiers of inflammatory responses [3,7]. Patients with compromised systemic conditions often exhibit altered wound healing capacity and increased susceptibility to inflammatory complications, potentially explaining the higher prevalence and severity of peri-implant disease observed in certain cohorts [6].

A history of chronic periodontitis is a well-established risk factor for peri-implantitis; however, metabolic disorders may potentiate this association by sustaining systemic inflammation and impairing host defense mechanisms [7,19]. The convergence of periodontal susceptibility and metabolic dysregulation creates a biological environment conducive to peri-implant tissue destruction, particularly in the absence of structured preventive maintenance [14,17]. Cross-sectional and longitudinal studies indicate that patients not enrolled in regular supportive care programs demonstrate higher peri-implant disease rates, a finding that may be further aggravated by uncontrolled metabolic conditions [3,18].

Soft tissue characteristics, such as insufficient keratinized mucosa, have been associated with increased peri-implant inflammation, especially in patients with suboptimal plaque control [10,15]. In metabolically compromised individuals, the protective role of keratinized tissue may become even more critical, as systemic inflammation can intensify local tissue reactions to bacterial biofilms [11]. Moreover, marginal bone loss, frequently reported in epidemiological studies, may progress more rapidly in patients with systemic conditions that impair bone metabolism and vascular function [9,12].

Population-based studies from diverse geographic regions confirm that peri-implant diseases are not restricted to specific demographic groups, suggesting that systemic modifiers, including metabolic status, contribute to disease expression across populations [16]. Importantly, long-term follow-up data demonstrate that peri-implant inflammation is cumulative over time, with higher incidence observed in patients exposed to multiple risk factors simultaneously [6,18]. Within this multifactorial framework, metabolic disorders should be regarded as significant systemic risk modifiers that interact with established local and behavioral determinants.

Collectively, the available evidence supports the inclusion of metabolic health assessment in peri-implant risk evaluation models. Although the reviewed studies do not uniformly stratify patients based on metabolic diagnoses, the consistent identification of systemic susceptibility factors underscores the necessity of integrating metabolic considerations into implant therapy planning and long-term maintenance strategies [1,4,17].

3. Pathophysiological Mechanisms Linking Metabolic Imbalance to Peri-implant Tissue Breakdown

The progression of peri-implant inflammation is governed by a dynamic interplay between microbial biofilms and host immune responses, with systemic metabolic imbalance acting as a critical modifier of these interactions. Although peri-implant diseases are initiated locally, their severity and progression are strongly influenced by host-related factors that regulate inflammatory and reparative mechanisms [1,2]. Clinical observations from epidemiological studies indicate that patients presenting multiple systemic and local risk indicators exhibit more pronounced peri-implant tissue breakdown, supporting a biologically plausible link between systemic dysregulation and peri-implant pathology [4,7].

Metabolic disorders are characterized by persistent low-grade inflammation, which may prime peri-implant tissues for an exaggerated inflammatory response. This systemic pro-inflammatory state can intensify local immune reactions to bacterial challenge, leading to increased soft tissue inflammation and accelerated marginal bone loss [5,9]. Long-term follow-up studies have shown that peri-implant lesions tend to progress over time, particularly in patients with compromised host response and irregular maintenance, suggesting impaired resolution of inflammation and defective tissue remodeling [6,14].

At the cellular level, metabolic imbalance may interfere with collagen turnover and extracellular matrix homeostasis, thereby compromising the structural integrity of peri-implant soft tissues. Clinical studies have demonstrated that insufficient keratinized mucosa and impaired soft tissue quality are associated with higher inflammatory indices and poorer peri-implant outcomes, effects that may be exacerbated in patients with systemic inflammatory burden [10,15]. These alterations facilitate plaque retention and perpetuate chronic inflammation at the implant–mucosa interface [11].

Bone metabolism is also adversely affected under conditions of systemic dysregulation. Marginal bone loss, frequently reported even in asymptomatic implants, reflects an imbalance between bone resorption and formation that may be accentuated by systemic factors influencing vascularization and osteoclastic activity [9,12]. In implant-supported full-arch rehabilitations, progressive bone resorption has been observed despite initial clinical success, highlighting the vulnerability of peri-implant bone to long-term biological stressors [13].

Genetic susceptibility further modulates host response to inflammatory stimuli. Associations between interleukin-6 gene polymorphisms and peri-implant disease suggest that individuals with a heightened inflammatory phenotype may experience amplified tissue destruction when exposed to systemic and local risk factors simultaneously [8]. Collectively, these mechanisms provide a coherent biological framework explaining how metabolic imbalance contributes to peri-implant tissue breakdown, reinforcing the multifactorial nature of peri-implant disease pathogenesis [16–19].

4. Clinical implications and Preventive Strategies in Metabolically Compromised Patients

The recognition of metabolic disorders as systemic modifiers of peri-implant disease necessitates a shift toward a more comprehensive and risk-oriented clinical approach in implant dentistry. Epidemiological evidence indicates that peri-implant inflammation is highly prevalent and tends to progress over time, particularly in patients exposed to multiple risk factors, underscoring the need for individualized treatment planning and long-term preventive strategies [1,4,6]. In metabolically compromised patients, conventional implant protocols may be insufficient to ensure sustained peri-implant tissue stability without targeted supportive measures.

Maintenance compliance emerges as one of the most decisive determinants of peri-implant health. Multiple studies demonstrate significantly higher rates of peri-implantitis in patients not enrolled in structured supportive care programs, irrespective of prosthetic design or implant type [3,14,17]. For patients with systemic metabolic imbalance, regular professional maintenance is particularly critical, as altered host response may limit the ability to control inflammation effectively through self-performed oral hygiene alone [7,18]. Consequently, shorter recall intervals and intensified monitoring of peri-implant parameters are recommended for high-risk individuals.

Clinical evaluation should extend beyond routine plaque and probing assessments to include careful appraisal of peri-implant soft tissue characteristics. The presence of adequate

keratinized mucosa has been repeatedly associated with improved peri-implant tissue health and reduced inflammatory burden, especially in patients with inconsistent maintenance compliance [10,15]. In metabolically compromised patients, ensuring favorable peri-implant soft tissue conditions may contribute to improved plaque control and enhanced resistance to inflammatory challenges [11].

Prosthetic and surgical considerations also influence long-term outcomes. Studies on implant-supported fixed and full-arch rehabilitations reveal that biological complications may occur despite satisfactory prosthetic function, highlighting the importance of biologic over purely mechanical success criteria [5,13]. Furthermore, patients with a history of chronic periodontitis require meticulous risk assessment, as long-term data demonstrate poorer implant prognosis in this population, particularly when systemic susceptibility factors coexist [19].

Preventive strategies should therefore integrate systemic health assessment into implant care protocols. Although the reviewed literature does not uniformly stratify patients by metabolic diagnosis, the consistent identification of systemic and behavioural risk indicators supports the inclusion of metabolic control as part of interdisciplinary patient management [2,4,16]. Ultimately, effective prevention of peri-implant disease in metabolically compromised patients relies on personalized maintenance programs, early detection of inflammatory changes, and sustained collaboration between dental and medical professionals [1,17].

Conclusions

Peri-implant inflammation is a prevalent and multifactorial biological complication that represents a major challenge for long-term implant success. Evidence from epidemiological and clinical studies indicates that disease onset and progression are influenced by the interaction between local risk factors, patient compliance, and systemic susceptibility. The cumulative nature of peri-implant tissue breakdown highlights the necessity of continuous monitoring and comprehensive risk assessment in implant therapy.

Metabolic disorders should be regarded as significant systemic modifiers that can amplify inflammatory responses and compromise peri-implant tissue stability. Although current clinical studies variably address metabolic status, the consistent association between systemic vulnerability, impaired maintenance, and peri-implant disease supports an interdisciplinary, prevention-oriented approach. Integrating metabolic control, personalized supportive care, and long-term follow-up into implant protocols is essential to reduce biological complications and improve clinical outcomes in high-risk patient populations.

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EVALUATION OF CLINICAL AND RADIOLOGICAL CRITERIA IN ESTABLISHING INDICATIONS FOR THIRD MOLAR EXTRACTION

Univ. Teaching Assist. Student Dorin Ioan COCOȘ Ph.D.^{1,2}; Assoc. Prof. Ramona Diana FEIER Ph.D.²; Professor, PhD Mariana PĂCURAR³; Prof. Kamel EARAR Ph.D.¹

¹Faculty of Dental Medicine, “Dunărea de Jos” University, 800008 Galați, Romania;

²Department of Dentistry, Faculty of Medicine, Dimitrie Cantemir University of Târgu Mureș, 540545 Târgu Mureș, România;

³“George Emil Palade” University of Medicine, Pharmacy, Science and Technology, Târgu Mureș, România, Faculty of Dental Medicine

Author correspondent: Ramona Diana FEIER: dr.ramonafeier@yahoo.ro; Mariana PĂCURAR: marianapac@yahoo.com

Abstract

The extraction of third molars remains one of the most common oral surgical procedures, yet its indication continues to be debated due to the variability of clinical presentations and radiological findings. This review evaluates the clinical and radiographic criteria used to establish clear and evidence-based indications for third molar extraction. Recent studies from 2000 to 2024 were analyzed, emphasizing diagnostic accuracy, risk-benefit balance, and long-term outcomes. Clinically, symptoms such as pericoronitis, pain, recurrent infection, and distal caries of adjacent molars are primary indicators for removal. Radiological assessment, particularly through panoramic radiography and cone-beam computed tomography (CBCT), provides essential information regarding tooth angulation, root morphology, and proximity to the mandibular canal or maxillary sinus. The integration of radiographic risk assessment systems, such as Pell and Gregory or Winter classifications, improves surgical planning and reduces complications. However, asymptomatic third molars still pose a management dilemma, as studies reveal potential risks of cyst formation, periodontal defects, and late crowding. The review concludes that extraction decisions should result from a combined clinical–radiological evaluation, considering patient age, pathology risk, and anatomical relations. Advances in CBCT imaging and digital predictive models are expected to refine diagnostic precision and support individualized decision-making in third molar management.

Keywords: third molar extraction, clinical criteria, radiographic assessment, CBCT, surgical indications, oral surgery

1. Clinical Criteria for Indicating Third Molar Extraction

The indication for third molar extraction is primarily grounded in clinical findings that demonstrate present or foreseeable pathology. Despite the high prevalence of impacted or partially erupted third molars, international consensus guidelines emphasize that extraction should not be routine but rather justified by clearly defined clinical criteria [1]. Health Technology Assessment (HTA) reports and national guidelines consistently underline the need for a pathology-driven approach, balancing surgical benefits against potential morbidity [2].

One of the most frequent and well-established clinical indications is pericoronitis, particularly when recurrent. Acute or chronic inflammation of the pericoronal tissues is associated with bacterial colonization facilitated by partial eruption and limited hygiene access. Recurrent episodes are linked to an increased risk of deep fascial space infections and systemic spread, supporting extraction as a definitive treatment rather than repeated antibiotic therapy [3]. Several guidelines explicitly list recurrent pericoronitis as an absolute indication for removal [4].

Pain of odontogenic origin, when directly attributable to the third molar and not explained by alternative diagnoses, represents another core indication. Persistent or episodic pain often reflects underlying inflammatory or infectious processes, even in the absence of overt swelling or suppuration. Clinical assessment must differentiate such pain from referred or temporomandibular sources; once confirmed, extraction is generally recommended to prevent progression [5].

Recurrent infection and associated soft tissue pathology further justify surgical intervention. Chronic inflammation around impacted third molars has been correlated with microbiological profiles similar to those observed in periodontitis, contributing to both local tissue destruction and adjacent tooth involvement. Retention in such cases increases cumulative morbidity and healthcare utilization [6].

A particularly significant indication is distal caries of the second molar caused by the presence of an impacted or partially erupted third molar. The anatomical configuration often promotes plaque retention at the distal cervical area of the second molar, which is difficult to detect clinically and frequently diagnosed at an advanced stage. Multiple guideline bodies recognize this scenario as a strong indication for extraction, especially when restorative prognosis of the second molar is compromised [7].

Closely related is periodontal pathology affecting the distal aspect of the second molar. Studies have demonstrated that retained third molars are associated with increased probing depths, attachment loss, and bone defects distal to the second molar, even in asymptomatic patients. Clinically evident periodontal deterioration, particularly when progressive, supports removal to preserve the periodontal health of the adjacent tooth [8].

Resorption of adjacent tooth roots, although less common, represents a definitive indication when diagnosed clinically and radiologically. Root resorption is often asymptomatic in early stages but may lead to irreversible damage of the second molar. Clinical suspicion arises in cases of unexplained mobility or sensitivity, and once confirmed, extraction of the etiological third molar is strongly recommended [9].

Third molars may also be implicated in cystic or tumoral pathology, such as dentigerous cysts or odontogenic tumors. Although diagnosis is primarily radiological, clinical signs such as swelling, cortical expansion, or delayed eruption warrant prompt surgical management. The presence of such pathology transforms an otherwise elective procedure into a therapeutic necessity [10].

Another relevant criterion involves functional and prosthetic considerations. Third molars may interfere with planned orthodontic movement, orthognathic surgery, or prosthetic rehabilitation. In such contexts, extraction is indicated to facilitate comprehensive treatment planning and long-term stability, provided that the risk–benefit ratio is favorable [11].

Importantly, the patient's age and systemic condition modulate clinical decision-making. Younger patients generally exhibit better healing capacity and lower complication rates, which may influence the timing of extraction when clear clinical indications exist. Conversely, in older patients, the presence of comorbidities necessitates stricter justification based on active pathology rather than prophylaxis [12].

The management of asymptomatic but clinically compromised third molars remains controversial. While some guidelines discourage prophylactic extraction, they acknowledge that the absence of symptoms does not equate to absence of disease. Clinical signs such as food impaction, localized gingival inflammation, or early periodontal changes may justify intervention when progression is likely [13].

HTA-based evaluations stress that clinical indications must be documented and reassessed periodically, particularly when extraction is deferred. Longitudinal monitoring is recommended to detect early pathological changes and avoid emergency surgery under unfavourable conditions [14].

Consensus reports further emphasize the importance of standardized clinical evaluation, including detailed history, periodontal assessment, and documentation of recurrent symptoms. This structured approach enhances diagnostic accuracy and supports medico-legal justification of the surgical decision [15].

In summary, current evidence supports third molar extraction when clear clinical pathology is present or when retention poses a predictable risk to adjacent structures. International guidelines converge on a conservative yet proactive strategy, advocating extraction based on documented clinical criteria rather than routine prophylaxis. Clinical judgment, informed by guideline-based indications and individualized patient assessment, remains central to optimal third molar management [16].

2. Radiological Assessment and Risk Stratification

Radiological evaluation plays a central role in establishing indications for third molar extraction, complementing clinical findings and significantly influencing surgical decision-making. Imaging allows precise assessment of tooth position, anatomical relationships, and potential surgical risks, thereby contributing to a more predictable and safer intervention. Current guidelines emphasize that radiographic examination is mandatory whenever clinical signs suggest pathology or when extraction is being considered [1,3].

Panoramic radiography remains the first-line imaging modality in third molar assessment. It provides a comprehensive overview of tooth angulation, eruption status, root development, and spatial relationships with adjacent anatomical structures. Panoramic imaging is particularly useful for identifying horizontal, mesioangular, or vertical impactions and for applying widely accepted classification systems, such as Pell and Gregory or Winter classifications, which facilitate standardized risk assessment and communication among clinicians [5,7]. These systems correlate the depth of impaction and the available retromolar space with surgical difficulty and complication risk.

A critical aspect of radiological assessment is the evaluation of the relationship between mandibular third molars and the inferior alveolar canal. Specific radiographic signs—such as canal diversion, darkening of the root, interruption of the canal cortex, or narrowing of the canal—are associated with an increased risk of inferior alveolar nerve injury. The identification of these markers on panoramic radiographs warrants heightened caution and may justify further imaging or modification of the surgical approach [3,8].

Cone-beam computed tomography (CBCT) has emerged as a valuable adjunctive tool in cases where panoramic findings suggest proximity to critical structures. CBCT allows three-dimensional visualization of root morphology, buccolingual positioning, and precise nerve-to-root relationships. Several guideline documents recommend CBCT selectively, not routinely, reserving its use for high-risk cases in which additional anatomical detail is expected to alter

clinical management or reduce surgical morbidity [6,10]. This selective approach aligns with radiation protection principles and cost-effectiveness considerations.

In the maxilla, radiological evaluation focuses on the relationship between third molars and the maxillary sinus. Panoramic imaging may reveal sinus floor approximation, but CBCT can more accurately assess sinus penetration or cortical integrity when sinus-related complications are anticipated [7,12]. Such information is essential for preventing oroantral communications and planning atraumatic extraction techniques.

Radiological findings also contribute to the detection of associated pathology, including follicular enlargement, cystic changes, or bone loss distal to the second molar. Even in clinically asymptomatic patients, radiographic evidence of progressive periodontal defects or pathological radiolucencies may shift the therapeutic balance toward extraction [9,13].

Importantly, radiological risk stratification must be interpreted in conjunction with clinical parameters. Guidelines consistently caution against basing extraction decisions solely on imaging findings, particularly in the absence of symptoms or documented disease [4,14]. Instead, radiology should refine, not replace, clinical judgment.

Radiological assessment is indispensable for risk stratification and surgical planning in third molar management. Panoramic radiography serves as an effective screening tool, while CBCT provides targeted, high-resolution information in selected high-risk cases. When integrated with clinical evaluation, radiological criteria enhance diagnostic accuracy, minimize complications, and support evidence-based, individualized decision-making [1,15,16].



Figure 1. Clinical and radiological aspects of impacted third molars.

In Figure 1, (a) Clinical intraoral view of a partially erupted mandibular third molar with pericoronal inflammation, illustrating a typical presentation of recurrent pericoronitis. (b) Panoramic radiograph (orthopantomogram) showing bilaterally impacted mandibular third molars with mesioangular orientation and close contact with the distal surfaces of the second molars. (c) Cone-beam computed tomography (CBCT) three-dimensional reconstruction highlighting the spatial relationship between an impacted mandibular third molar and the inferior alveolar nerve, relevant for radiological risk stratification.

3. Management of Asymptomatic and Disease-Free Third Molars

The management of asymptomatic and disease-free third molars remains one of the most debated issues in oral and maxillofacial surgery. While these teeth may be clinically silent at the time of evaluation, extensive guideline-based analyses emphasize that the absence of symptoms does not necessarily equate to the absence of pathology or future risk [1,3]. Consequently, contemporary recommendations advocate for a cautious, evidence-based approach that prioritizes surveillance over routine prophylactic extraction.

Multiple Health Technology Assessment reports and national guidelines converge on the conclusion that systematic prophylactic removal of asymptomatic third molars is not supported by high-quality evidence [2,4]. Longitudinal studies fail to demonstrate clear long-term benefits that would outweigh the inherent surgical risks, including nerve injury, infection, and delayed healing. As a result, several authoritative bodies explicitly discourage extraction in the absence of clinical or radiological disease [6,7].

Nevertheless, retention of asymptomatic third molars is not without potential consequences. Evidence indicates that these teeth may be associated with late-onset pathology, including periodontal defects distal to the second molar, carious lesions, and cystic degeneration of the follicular sac [5,8]. Such conditions often develop insidiously and may only become clinically apparent when advanced, potentially complicating subsequent management. This underlines the importance of careful case selection and ongoing monitoring.

Periodontal implications are particularly relevant. Studies cited in guideline documents report a higher prevalence of increased probing depths and attachment loss adjacent to retained mandibular third molars, even in patients without subjective complaints [9,10]. These findings suggest that asymptomatic status may mask subclinical disease processes capable of compromising the long-term prognosis of the second molar.

Patient-related factors significantly influence decision-making in this context. Age is a critical determinant, as younger patients generally experience fewer postoperative complications and more favorable healing. However, guidelines caution against using age alone as an indication for prophylactic extraction, emphasizing that the presence of demonstrable pathology remains the decisive factor [11,12]. In older patients, surgical morbidity increases, reinforcing the recommendation for conservative management unless clear disease develops.

Several guideline panels advocate for active surveillance protocols when asymptomatic third molars are retained. These include periodic clinical examinations, radiographic reassessment, and patient education regarding early warning signs of pathology [13]. This strategy aims to identify disease at an early, manageable stage while avoiding unnecessary surgical intervention.

From a public health and economic perspective, systematic reviews and HTA analyses highlight that prophylactic extraction of disease-free third molars does not represent a cost-effective use of healthcare resources [3,14]. The financial burden of surgery and management of complications outweighs the uncertain benefit of preventing future pathology in a subset of patients.

Current evidence supports a conservative, individualized approach to asymptomatic and disease-free third molars. Routine prophylactic extraction is not justified, while structured monitoring remains essential to ensure timely intervention should pathology arise. This balanced strategy aligns with evidence-based guidelines and optimizes patient safety and resource allocation [1,15,16].

4. Integrated Clinical–Radiological Decision-Making and Guidelines Perspective

The establishment of indications for third molar extraction requires an integrated decision-making model that synthesizes clinical findings with radiological assessment, in alignment with evidence-based guidelines. Contemporary recommendations consistently emphasize that neither clinical nor radiographic criteria should be interpreted in isolation, as this may lead to overtreatment or delayed intervention with increased morbidity [1,3].

Clinical evaluation provides the initial framework by identifying symptoms, recurrent inflammatory episodes, or functional impairment attributable to third molars. Radiological imaging subsequently refines this assessment by clarifying tooth position, anatomical relationships, and potential surgical risks. When combined, these data allow for a more accurate estimation of disease progression and operative difficulty, supporting a rational risk–benefit analysis [5,7].

Guideline-based approaches underscore the importance of individualized treatment planning. Factors such as patient age, systemic health, oral hygiene status, and compliance with follow-up must be weighed alongside anatomical considerations. Younger patients may benefit from earlier intervention when clear indications are present, whereas in older individuals a more conservative strategy is often warranted due to increased surgical risk [2,6]. This patient-centered perspective is a recurring theme across international consensus documents.

Radiological risk stratification, particularly in relation to the inferior alveolar nerve or maxillary sinus, plays a pivotal role in determining not only whether extraction is indicated, but also how it should be performed. High-risk anatomical configurations may justify modified surgical techniques, delayed intervention, or continued monitoring in the absence of active disease [8,10]. Such adaptations reflect a shift from uniform protocols toward tailored surgical strategies.

Guidelines also emphasize the necessity of documented decision-making, especially in borderline cases such as asymptomatic third molars. Thorough recording of clinical findings, radiographic interpretation, and patient counseling enhances transparency and medico-legal defensibility [4,11]. Informed consent is integral to this process, requiring clear communication of potential benefits, risks, and alternatives.

From a broader healthcare perspective, integrated decision-making aligns with principles of cost-effectiveness and resource optimization. Avoiding unnecessary extractions reduces complication-related expenditures while preserving access to surgical care for patients with definitive pathology [3,14].

The integration of clinical and radiological criteria within a guideline-based framework represents the cornerstone of contemporary third molar management. This approach supports precise, individualized decisions, minimizes avoidable morbidity, and ensures that extraction is undertaken only when justified by a demonstrable therapeutic benefit [1,15,16].

Table 1. Integrated clinical and radiological criteria for third molar extraction

Criterion category	Specific findings	Imaging relevance	Ref.
Clinical pathology	Recurrent pericoronitis, pain, infection	Confirms extent of local inflammation	[1,3,4]
Adjacent tooth risk	Distal caries or periodontal defects of second molar	Detects bone loss and carious lesions	[5,7,8]
Anatomical risk	Proximity to inferior alveolar nerve or maxillary sinus	CBCT for three-dimensional risk assessment	[6,10]

Asymptomatic status	No symptoms, no evident pathology	Radiological monitoring recommended	[2,9,14]
Decision framework	Clinical–radiological correlation	Supports individualized treatment planning	[11,15,16]

Table1, Summary of the main clinical and radiological criteria used in establishing indications for third molar extraction, correlated with guideline-based and evidence-derived recommendations.

Conclusions

The indication for third molar extraction should be based on a rigorous integration of clinical and radiological criteria, with priority given to documented pathology rather than routine or prophylactic removal. This evidence-based approach minimizes unnecessary surgical interventions while ensuring timely treatment of disease.

Radiological assessment, particularly when used selectively to complement clinical findings, enhances diagnostic accuracy, surgical planning, and risk stratification. Its appropriate use contributes significantly to reducing operative complications and optimizing patient outcomes.

Management of asymptomatic third molars requires individualized decision-making and structured long-term monitoring. Adherence to international guidelines supports a balanced strategy that protects adjacent structures, respects patient-specific risk factors, and promotes safe, cost-effective oral surgical care.

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NEXT-GENERATION BIOMATERIALS FOR THE HEALING OF INFECTED ORAL LESIONS: ANTIBACTERIAL, IMMUNOMODULATORY, METABOLICALLY ACTIVE, AND PSYCHONEUROIMMUNOLOGICAL PERSPECTIVES

University Teaching Assistant, Ph.D. Student Dorin Ioan COCOȘ¹; University Teaching Assistant Ph.D. Student Cristian COJOCARIU¹; Ph.D. Student Cristina BAZBANELA², Assoc. Prof Ramona Diana FEIER Ph.D.³; Ph.D. Student Monica DINU²; University Teaching Assistant, Ph.D. Student Irinel LUNGU²; Assoc. Prof. Sorina-Mihaela BĂLAN Ph.D.³

¹Faculty of Dental Medicine, “Dunărea de Jos” University, 800008 Galați, Romania;

²Centre in the Medical-Pharmaceutical Field, Faculty of Medicine and Pharmacy, “Dunărea de Jos” University of Galați, 800008 Galați, Romania;

³Department of Dentistry, Faculty of Medicine, Dimitrie Cantemir University of Târgu Mureș, 540545 Târgu Mureș, Romania

Corresponding - Ramona Diana FEIER: dr.ramonafeier@yahoo.ro; Sorina-Mihaela BăLAN: bsorinamihaela@yahoo.com

Abstract

Infected oral lesions represent a persistent clinical challenge due to complex microbial biofilms, dysregulated inflammation, metabolic imbalance, and impaired tissue regeneration. Conventional antimicrobial therapies often fail to adequately address these multifactorial mechanisms, prompting the development of next-generation biomaterials with integrated biological functions. This review synthesizes current advances in antibacterial, immunomodulatory, and metabolically active biomaterial strategies, emphasizing their relevance to the unique microenvironment of infected oral tissues. Intrinsic antibacterial hydrogels, metal-based systems, and biofilm-responsive platforms provide localized infection control while reducing reliance on systemic antibiotics. Concurrently, immunomodulatory materials targeting inflammatory pathways and macrophage polarization facilitate the transition from chronic inflammation to regenerative healing. Metabolically active biomaterials, including oxygen-generating and glucose-responsive systems, further enhance angiogenesis, cellular energy balance, and immune efficiency. Beyond local biological effects, these multifunctional platforms indirectly influence psychoneuroimmunological pathways by reducing pain, inflammation, and treatment burden, factors closely associated with stress-related delayed healing. By integrating material science with host–microenvironment interactions, next-generation biomaterials offer a comprehensive and patient-centred approach for improving outcomes in infected oral lesion management and highlight promising directions for future translational research.

Keywords: oral wound healing, antibacterial biomaterials, immunomodulation, metabolic regulation, biofilm control, psychoneuroimmunology

1. Antibacterial Biomaterials Targeting Infected Oral Microenvironments

Infected oral lesions represent a complex pathological niche characterized by high microbial load, structured biofilms, persistent inflammation, and impaired tissue regeneration. Conventional antimicrobial strategies are often insufficient in this context due to limited penetration into biofilms, rapid clearance by saliva, and the increasing prevalence of antimicrobial resistance. Consequently, next-generation biomaterials are being developed to exert intrinsic, localized, and microenvironment-responsive antibacterial effects, while simultaneously supporting tissue healing [1].

A major advance in this field is represented by hydrogels with inherent antibacterial activity, which do not rely solely on the release of conventional antibiotics. Dendritic hydrogels, for example, exhibit robust bactericidal effects through contact-mediated membrane disruption, electrostatic interactions, and structural interference with bacterial cell walls. These materials demonstrate sustained antibacterial efficacy even in heavily infected wounds, reducing bacterial burden while preserving cytocompatibility with host tissues [1]. Such properties are particularly relevant for oral lesions, where continuous microbial challenge and mechanical stress demand stable and long-lasting antibacterial function.

Beyond intrinsic antibacterial, modern wound-care research emphasizes the importance of advanced dressing concepts, integrating antimicrobial control with moisture balance, oxygen diffusion, and biological signalling. Although initially developed for diabetic skin wounds, advanced bandage paradigms provide transferable design principles for oral biomaterials, particularly regarding infection control in metabolically compromised tissues [2]. These platforms highlight the necessity of combining antibacterial action with regenerative support rather than treating infection as an isolated target.

Metal-based antibacterial systems represent another important category. The structural design of polymeric matrices capable of chelating or imprinting metal ions, such as copper, enables controlled antibacterial activity through ion-mediated oxidative stress and enzyme inhibition in bacteria [3]. Such approaches underscore the relevance of material architecture in regulating antimicrobial potency while minimizing cytotoxicity. Given the substantial global burden of chronic and infected wounds, including oral lesions, these material-driven strategies respond to a clear and growing clinical need [4].

More recent developments move beyond passive antibacterial release toward bioactive and adaptive systems. Living microecological hydrogels exemplify this shift by incorporating beneficial microorganisms or biologically active components that compete with pathogenic bacteria and restore microbial balance. These systems redefine antibacterial therapy as an ecological modulation process rather than indiscriminate bacterial eradication [5]. In parallel, ECM-mimetic immunomodulatory hydrogels have demonstrated the capacity to suppress pathogenic bacteria indirectly by attenuating excessive inflammation and restoring host defense mechanisms, thereby creating an unfavourable environment for microbial persistence [6].

Metabolic manipulation has also emerged as a novel antibacterial strategy. Photocatalytic biomaterials capable of local glucose depletion deprive bacteria of essential nutrients while simultaneously generating therapeutic byproducts such as hydrogen, which can modulate oxidative stress and inflammation. This dual mechanism has proven effective in infected wounds, particularly under diabetic conditions where hyperglycaemia promotes bacterial proliferation [7]. Complementary molecular approaches targeting intracellular signalling pathways involved in tissue repair and angiogenesis further enhance host resistance to infection by accelerating barrier restoration [8].

A critical challenge in oral infections is the resilience of structured biofilms, which shield bacteria from immune responses and antimicrobial agents. Biofilm-responsive platforms, such as photodynamic and immunomodulatory microneedle systems, activate antibacterial effects selectively within the biofilm microenvironment, thereby enhancing efficacy while limiting off-target damage [9].

Similarly, nanoscale silver-embedded gels provide potent antibacterial activity by inhibiting bacterial adhesion and colonization at the wound surface, while also exerting anti-inflammatory effects that support healing [10].

The interplay between infection, inflammation, and systemic metabolic dysregulation further complicates oral wound healing. Modulation of inflammatory receptors and signalling axes involved in chronic metabolic disease has been shown to reduce susceptibility to infection and improve tissue outcomes [11].

At the same time, bacterial pathogens demonstrate remarkable adaptability to hyperinflammatory environments, reinforcing the need for biomaterials capable of dynamically responding to host–pathogen interactions [12].

Figure 1. Pathophysiological microenvironment of infected oral lesions

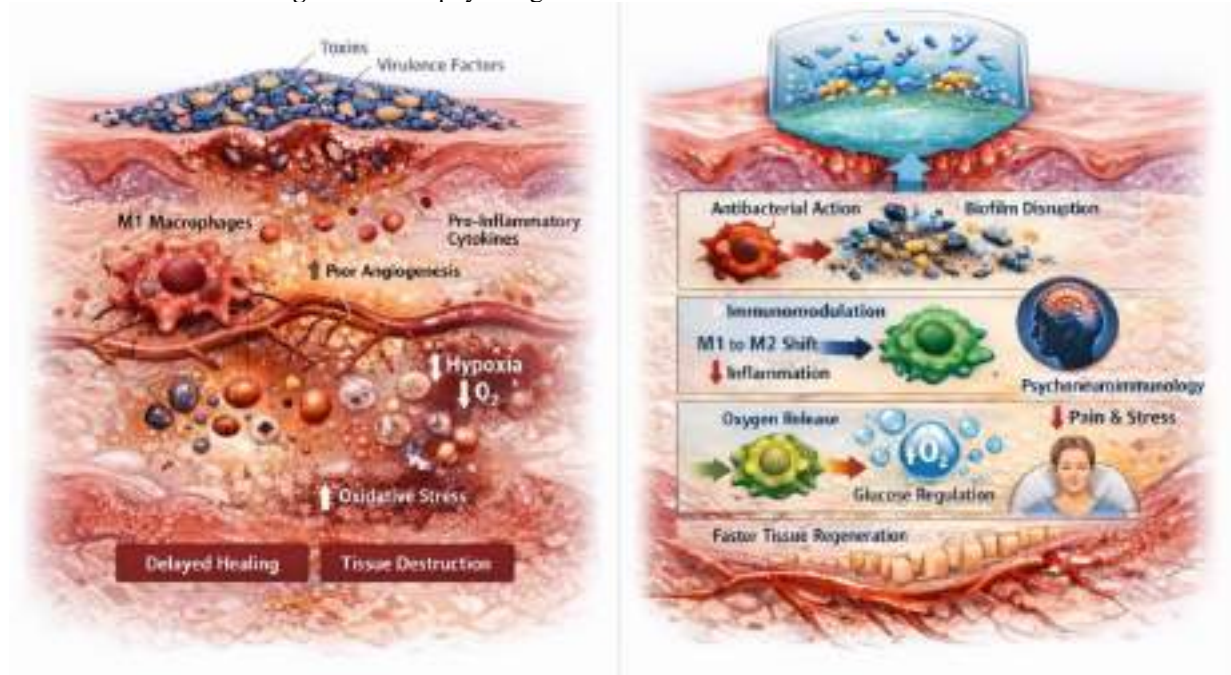


Figure 1. Schematic representation of the pathophysiological microenvironment of infected oral lesions. The illustration highlights the coexistence of structured bacterial biofilms, persistent pro-inflammatory immune activity dominated by M1 macrophages, hypoxia, oxidative stress, impaired angiogenesis, and metabolic dysregulation. These interconnected factors promote tissue destruction and delayed healing, creating a self-sustaining pathological niche that challenges conventional antimicrobial and regenerative therapies.

Emerging bioengineering strategies extend antibacterial control beyond the wound surface. Metabolically active constructs designed to normalize systemic glucose levels indirectly reduce infection risk by correcting the biochemical milieu that favors bacterial growth [13]. Oxygen-generating biomaterials, including microalgae-based systems, further suppress anaerobic

bacterial populations while enhancing host cell function and angiogenesis [14]. Enzyme-linked and self-powered microneedle platforms integrate antibacterial, anti-inflammatory, and regenerative cues into a single system, illustrating the trend toward multifunctional designs [15,16].

Finally, insights from pharmacological modulation of metabolism and inflammation, including agents such as metformin and natural phenolic compounds, inform the development of biomaterials incorporating bioactive small molecules with ancillary antibacterial effects [17–19]. Encapsulation of compounds like eugenol into nanoparticulate carriers enhances their antibacterial potency and stability, particularly against gram-positive oral pathogens [20]. Advanced peptide-based and bio fabricated hydrogel platforms further expand the antibacterial arsenal by enabling precise spatial control of cellular and molecular interactions within infected tissues [21].

2. Immunomodulatory Biomaterials for Inflammation Control and Tissue Regeneration

Infected oral lesions are characterized not only by microbial invasion but also by a dysregulated host immune response, which plays a decisive role in tissue destruction, delayed healing, and chronicity. Excessive or prolonged inflammation alters vascular permeability, impairs fibroblast and keratinocyte function, and favors bacterial persistence. Consequently, next-generation biomaterials increasingly aim to modulate the local immune microenvironment, rather than merely suppress infection, thereby restoring the physiological sequence of inflammation, proliferation, and remodelling [2,4].

A central strategy in immunomodulatory biomaterial design is the control of macrophage polarization. ECM-mimetic hydrogels have demonstrated the capacity to shift macrophages from a pro-inflammatory M1 phenotype toward a reparative M2 profile, leading to reduced cytokine release, enhanced angiogenesis, and accelerated tissue regeneration in infected wounds [6]. This mechanism is particularly relevant for oral tissues, where persistent exposure to microbial antigens maintains macrophages in a chronically activated state, contributing to mucosal breakdown and impaired healing.

Beyond macrophage polarization, immunomodulatory biomaterials exert effects through attenuation of excessive inflammatory signalling. Hydrogels and advanced wound platforms designed for chronic wounds illustrate how dampening inflammatory cascades can indirectly reduce bacterial virulence and biofilm stability by normalizing the tissue microenvironment [1,2]. In this context, inflammation is no longer viewed solely as a defensive response but as a pathological driver when unchecked, especially in metabolically compromised conditions.

Recent molecular insights have further refined immunomodulatory strategies. Inhibition of intracellular mediators involved in inflammatory and reparative signalling, such as CXXC5, has been shown to enhance angiogenesis and epithelial repair, accelerating wound closure while limiting inflammatory damage [8]. Similarly, modulation of the RAGE-associated signalling axis reduces chronic inflammatory stress and improves tissue resilience, underscoring the relevance of targeting immune–metabolic crosstalk in infected lesions [11]. These mechanisms are highly applicable to oral pathology, where systemic inflammatory burden often exacerbates local disease.

Immunomodulation also plays a key role in counteracting bacterial adaptation to hostile inflammatory environments.

Certain pathogens exhibit enhanced survival in hyperinflammatory niches by exploiting immune-derived nutrients and oxidative stress. Studies demonstrating bacterial adaptation in diabetic wounds highlight the importance of biomaterials capable of normalizing immune

responses to prevent the establishment of such permissive environments [12]. By reducing excessive inflammation, immunomodulatory biomaterials indirectly limit bacterial fitness and persistence.

Emerging platforms integrate immunomodulatory functions with stimuli-responsive activation. Biofilm-triggered photodynamic and immunomodulatory systems exemplify how targeted immune activation can be synchronized with antibacterial action, promoting effective bacterial clearance while minimizing collateral tissue damage [9]. This approach is particularly advantageous in oral tissues, where preserving mucosal integrity is essential for function and patient comfort.

Metabolic regulation further intersects with immune control. Hyperglycaemia and metabolic dysregulation amplify inflammatory signalling, impair leukocyte function, and delay wound healing. Biomaterials addressing local metabolic imbalances, including glucose-responsive or oxygen-releasing systems, indirectly modulate immune activity by restoring cellular energy homeostasis and reducing hypoxia-induced inflammation [7,14,16]. These effects contribute to a more balanced immune response conducive to regeneration.

Finally, natural bioactive compounds incorporated into biomaterials provide additional immunomodulatory benefits. Phenolic molecules such as eugenol exhibit anti-inflammatory properties alongside antibacterial activity, particularly when stabilized within nano- or hydrogel carriers [18–20]. Their inclusion enhances local immune regulation without systemic side effects, aligning with the principles of localized therapy in oral medicine.

3. Metabolically Active Biomaterials for Correcting Hypoxia and Dysregulated Energy Microenvironments

Infected oral lesions are frequently associated with metabolic imbalance and tissue hypoxia, both of which critically impair immune competence and regenerative capacity. Persistent inflammation, vascular dysfunction, and high microbial metabolic demand converge to create a hostile microenvironment characterized by reduced oxygen tension, elevated glucose availability, and oxidative stress. Metabolically active biomaterials have emerged as a novel therapeutic class designed to actively regulate local biochemical conditions, thereby supporting host-driven healing while indirectly suppressing bacterial survival [2,4].

One of the most extensively explored strategies is local oxygen delivery. Sustained oxygenation has been shown to accelerate epithelialization, enhance angiogenesis, and reduce inflammatory cytokine expression in chronic wounds [16]. In the context of oral lesions, where microvascular compromise and edema are common, oxygen-releasing biomaterials counteract hypoxia-driven fibroblast dysfunction and impaired collagen synthesis. Microalgae-based gel systems exemplify biologically inspired oxygen-generating platforms, producing dissolved oxygen in situ and significantly improving wound closure and vascularization under diabetic and infected conditions [14]. These effects are particularly relevant for anaerobic and facultative anaerobic oral pathogens, whose proliferation is inhibited in oxygen-enriched environments.

Beyond oxygen modulation, glucose-responsive biomaterials address the metabolic substrate availability that fuels both bacterial growth and chronic inflammation. Photocatalytic systems capable of depleting local glucose simultaneously restrict bacterial energy sources and mitigate hyperglycaemia-induced immune dysfunction. The associated generation of hydrogen further contributes to antioxidative and anti-inflammatory effects, reinforcing tissue repair processes [7]. This dual metabolic–immunological modulation is especially pertinent in oral wounds in patients with systemic metabolic disorders, where elevated glucose levels perpetuate infection and delayed healing.

Metabolic regulation at the cellular level also plays a decisive role. Engineered constructs enhancing glucose uptake and utilization by host tissues have demonstrated improved systemic glycaemic control and tissue regeneration, indirectly reducing infection susceptibility [13]. Although initially investigated in muscular systems, these concepts inform the development of oral biomaterials designed to optimize cellular energy metabolism within the wound bed. Restoration of efficient energy utilization supports fibroblast proliferation, keratinocyte migration, and immune cell function, all of which are essential for oral mucosal repair.

The interdependence between metabolism and inflammation further underscores the relevance of metabolically active biomaterials. Chronic metabolic stress amplifies inflammatory signaling pathways, while inflammation exacerbates metabolic dysfunction. Oxygen- and enzyme-based biomaterials disrupt this vicious cycle by normalizing redox balance and cellular respiration, thereby attenuating inflammatory persistence [15,16]. In addition, metabolic interventions reduce the selective pressure that enables bacterial adaptation to hostile environments, limiting pathogen resilience [12].

Natural metabolic modulators provide additional translational opportunities. Compounds such as metformin and plant-derived phenolics influence glucose metabolism and inflammatory tone, offering mechanistic insights for incorporation into biomaterial platforms [17–19]. When combined with controlled-release matrices, these agents can exert localized metabolic effects without systemic exposure, aligning with the principles of precision oral therapy.

4. Multifunctional Biomaterial Platforms and Translational Perspectives for Infected Oral Lesions

The increasing complexity of infected oral lesions has driven the development of multifunctional biomaterial platforms capable of simultaneously addressing bacterial burden, immune dysregulation, and metabolic impairment. Rather than relying on single-mechanism interventions, contemporary research emphasizes integrated systems that dynamically interact with the wound microenvironment, offering coordinated antibacterial, immunomodulatory, and regenerative effects [1,2].

One prominent direction is the design of stimuli-responsive biomaterials that activate therapeutic functions in response to infection-specific cues such as pH changes, enzymatic activity, or biofilm formation. Biofilm-triggered photodynamic and immunomodulatory systems exemplify this concept, enabling localized bacterial eradication while minimizing damage to surrounding tissues [9]. Such precision is particularly valuable in the oral cavity, where structural and functional preservation of mucosa is essential.

Advanced microneedle-based platforms further extend multifunctionality by facilitating controlled trans-tissue delivery of therapeutic agents. Enzyme-linked and self-powered microneedle systems integrate metabolic regulation, anti-inflammatory signalling, and tissue remodelling into a single construct, enhancing therapeutic penetration and spatial accuracy [15,16]. Although initially developed for cutaneous applications, these technologies provide a conceptual framework for oral and peri-oral lesions requiring localized yet effective intervention.

Living and bioactive materials represent another emerging class of multifunctional systems. Microecological hydrogels incorporating biologically active components demonstrate the ability to restore tissue homeostasis by modulating both microbial populations and host responses [5]. These materials challenge traditional sterile paradigms by leveraging controlled biological activity to suppress pathogenic dominance and promote regeneration. When

combined with ECM-mimetic architectures, such platforms support cellular adhesion, migration, and angiogenesis while maintaining antimicrobial control [6].

From a translational perspective, the incorporation of metabolically active elements significantly enhances the clinical relevance of multifunctional biomaterials. Oxygen-generating systems and glucose-responsive platforms improve tissue perfusion, reduce inflammatory persistence, and indirectly limit bacterial survival, thereby reinforcing the efficacy of antibacterial and immunomodulatory components [7,14,16]. The convergence of these mechanisms is particularly pertinent for oral lesions associated with systemic metabolic disorders, where local therapy must compensate for impaired systemic regulation.

The integration of bioactive small molecules into multifunctional matrices further broadens therapeutic potential. Natural compounds with combined antibacterial and anti-inflammatory properties, such as phenolic derivatives, offer favourable safety profiles and synergistic effects when delivered via controlled-release biomaterials [18–20]. Their inclusion supports a shift toward localized, low-toxicity interventions tailored to the oral environment.

Despite these advances, several translational challenges remain. The oral cavity presents unique constraints, including continuous salivary flow, mechanical stress from mastication, and a highly diverse microbiome. Multifunctional biomaterials must therefore demonstrate adequate adhesion, stability, and biocompatibility under these conditions while maintaining precise control over therapeutic release [4]. Furthermore, scalability, reproducibility, and regulatory considerations will influence the clinical adoption of these advanced platforms.

Table 1. Functional overview of next-generation biomaterial strategies for infected oral lesion healing

Biomaterial strategy	Primary biological target	Mechanism of action	Therapeutic relevance for infected oral lesions	Ref
Intrinsic antibacterial hydrogels	Bacterial cell membrane, biofilm	Contact-mediated membrane disruption, electrostatic interactions	Direct bacterial eradication, reduced biofilm persistence	(1)
Advanced wound dressing concepts	Infection-regeneration imbalance	Combined infection control and regenerative support	Framework for multifunctional oral biomaterials	(2,4)
Metal-based polymeric systems	Bacterial enzymes, oxidative balance	Ion-mediated oxidative stress, enzyme inhibition	Antibacterial efficacy with controlled cytotoxicity	(3)
Living microecological hydrogels	Microbial ecosystem	Competitive microbial modulation, ecological balance restoration	Biofilm destabilization and microbiome regulation	(5)
ECM-mimetic immunomodulatory hydrogels	Host immune response	Macrophage polarization (M1→M2), cytokine regulation	Inflammation control and enhanced tissue repair	(6)
Photocatalytic metabolic biomaterials	Glucose-rich microenvironment	Local glucose depletion, hydrogen generation	Reduced bacterial growth, anti-inflammatory effects	(7)
Molecular immunoregulatory targeting	Inflammatory and angiogenic pathways	Modulation of intracellular repair signaling	Accelerated epithelialization and angiogenesis	(8,11)
Biofilm-triggered photodynamic platforms	Biofilm microenvironment	Stimuli-responsive antibacterial and immune activation	Targeted biofilm disruption with minimal tissue damage	(9)

Biomaterial strategy	Primary biological target	Mechanism of action	Therapeutic relevance for infected oral lesions	Ref
Silver nanoparticle-based gels	Bacterial adhesion and inflammation	Inhibition of colonization, anti-inflammatory action	Improved infection control and wound healing	(10)
Metabolically active constructs	Glucose metabolism	Enhanced glucose uptake and utilization	Indirect reduction of infection susceptibility	(13,17,19)
Oxygen-generating biomaterials	Tissue hypoxia	Sustained oxygen release, angiogenesis promotion	Improved healing, suppression of anaerobic bacteria	(14,16)
Enzyme-linked microneedle systems	Local metabolic imbalance	Self-powered metabolic regulation and delivery	Precision therapy for chronic infected lesions	(15)

Continuing Table 1. Functional overview of next-generation biomaterial strategies for infected oral lesion healing

Table 1. Summary of next-generation biomaterial strategies categorized according to their primary biological targets, mechanisms of action, and therapeutic relevance for infected oral lesions. The table highlights the integration of antibacterial, immunomodulatory, and metabolically active approaches that collectively address biofilm persistence, inflammatory dysregulation, hypoxia, and impaired tissue regeneration, based on the referenced literature.

5. Psychoneuroimmunological and Psychosomatic Dimensions in the Healing of Infected Oral Lesions

Healing of infected oral lesions is increasingly recognized as a multidimensional process influenced not only by local biological factors but also by systemic neuroendocrine and psychosomatic mechanisms. Psychological stress, anxiety, and behavioral responses to disease modulate immune competence, inflammatory balance, and metabolic regulation, thereby indirectly shaping the local wound microenvironment. Although the current literature on advanced biomaterials primarily addresses biological mechanisms, the pathways described within these studies provide a solid framework for integrating a psychoneuroimmunological perspective into oral wound management [2,4].

Chronic psychological stress is biologically associated with sustained inflammatory activation, impaired angiogenesis, and delayed epithelial repair. These processes overlap mechanistically with the pathological features targeted by immunomodulatory biomaterials, particularly those designed to attenuate excessive inflammation and promote macrophage polarization toward reparative phenotypes [6,11]. By reducing local inflammatory burden, such biomaterials may indirectly counteract stress-related amplification of cytokine signalling, creating conditions favourable for tissue regeneration.

Metabolic dysregulation represents a key interface between psychological stress and wound healing. Stress-related neuroendocrine responses are known to exacerbate glucose imbalance and oxidative stress, factors that favour bacterial proliferation and impair immune function. Biomaterials capable of modulating glucose availability or enhancing cellular metabolic efficiency address these pathways at the tissue level, mitigating the downstream effects of systemic stress on local healing processes [7,13,17]. In this context, metabolically active biomaterials function not only as local therapeutic agents but also as modulators of stress-sensitive biological circuits.

Hypoxia constitutes another critical link between psychosomatic stress and impaired wound repair. Stress-induced vasoconstriction and endothelial dysfunction contribute to reduced tissue oxygenation, reinforcing inflammatory persistence and bacterial survival. Oxygen-generating biomaterials and sustained oxygenation platforms directly counteract these effects by restoring adequate oxygen tension, improving angiogenesis, and normalizing cellular respiration [14,16]. These interventions may indirectly reduce pain and discomfort; factors closely associated with psychological distress in patients with chronic oral lesions.

The perception of pain and treatment burden further influences healing outcomes through behavioural and psychological pathways. Persistent pain exacerbates stress responses and negatively affects patient compliance with oral hygiene and postoperative care. Multifunctional biomaterial platforms that combine antibacterial, anti-inflammatory, and regenerative functions reduce lesion chronicity and treatment duration, potentially alleviating psychological strain associated with prolonged disease [1,9,15]. In this sense, advanced biomaterials contribute to a more favourable psychosomatic healing environment by simplifying therapeutic protocols and improving patient experience.

The adaptability of bacterial pathogens to hyperinflammatory and metabolically stressed environments highlights the importance of stabilizing host-related factors. By normalizing inflammation, metabolism, and oxygenation, biomaterial-based interventions indirectly disrupt the feedback loops that link psychological stress to microbial persistence [12]. This systems-level interaction underscores the relevance of integrating psychoneuroimmunological considerations into the design and evaluation of oral biomaterials.

Conclusions

Next-generation biomaterials represent a paradigm shift in the management of infected oral lesions by transcending conventional antimicrobial strategies and addressing the multifactorial nature of impaired healing. The integration of intrinsic antibacterial properties, immunomodulatory functions, and metabolically active components enables precise control of the local wound microenvironment. By targeting biofilm persistence, inflammatory dysregulation, hypoxia, and metabolic imbalance, these advanced systems support coordinated tissue regeneration while minimizing reliance on systemic therapies. Such approaches are particularly relevant for oral tissues, where complex microbial ecology and constant mechanical stress challenge traditional treatment modalities.

Beyond their biological efficacy, emerging biomaterial platforms offer important translational advantages by indirectly influencing host-related and psychosomatic factors that modulate healing outcomes. Through reduction of pain, inflammation, and treatment duration, multifunctional systems may alleviate stress-related biological responses that perpetuate chronicity in oral lesions. Framing biomaterial-based therapies within a psychoneuroimmunological context enhances their clinical relevance and supports a patient-centered model of care. Future research should prioritize integrative designs that combine material innovation with an improved understanding of host–microenvironment interactions, facilitating personalized and sustainable solutions for infected oral wound management.

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EVALUATION OF THE EFFECTIVENESS OF LAVENDER OIL IN CONTROLLING GINGIVAL INFLAMMATION AND ORAL INFECTIONS: EXPERIMENTAL DATA, CLINICAL APPLICATIONS, AND PSYCHOPHYSIOLOGICAL IMPLICATIONS

Univ. Teach. Assist. Ph.D. Student Dorin Ioan COCOȘ¹, Prof. Mariana PĂCURAR Ph.D.², Assoc. Prof. Ramona Diana FEIER Ph.D.³; Assoc. Prof. Sorina-Mihaela BĂLAN Ph.D.³; Professor Kamel EARAR Ph.D.¹

¹Faculty of Dental Medicine, "Dunărea de Jos" University, 800008 Galați, Romania;

²"George Emil Palade" University of Medicine, Pharmacy, Science and Technology, Târgu Mureș, România, Faculty of Dental Medicine;

³Department of Dentistry, Faculty of Medicine, Dimitrie Cantemir University of Târgu Mureș, 540545 Târgu Mureș, România

Corresponding: Ramona Diana FEIER: dr.ramonafeier@yahoo.ro; Sorina-Mihaela BĂLAN: bsorinamihaela@yahoo.com

Abstract

Lavender (*Lavandula angustifolia*) essential oil has attracted growing interest in dentistry due to its complex biological activity and favorable psychophysiological effects. This review synthesizes experimental, in vitro, and clinical evidence regarding the effectiveness of lavender oil in controlling gingival inflammation and oral infections, while also addressing its impact on pain perception, anxiety modulation, and stress-related immune responses. Experimental studies demonstrate broad-spectrum antimicrobial activity against key oral pathogens and inhibition of microbial adhesion and biofilm formation, alongside significant anti-inflammatory and antioxidant effects at the cellular level. Clinical investigations support its adjunctive use in gingival and mucosal inflammatory conditions, denture-related infections, pain reduction, and anxiety control in both adult and pediatric dental patients. Moreover, psychophysiological data indicate that lavender oil modulates autonomic and neuroendocrine responses, including reductions in salivary cortisol, thereby indirectly influencing oral immune homeostasis and tissue healing. Advances in pharmaceutical formulations and biomaterial integration further enhance its translational potential. Although generally well tolerated, standardized protocols and safety considerations remain essential. Overall, lavender oil emerges as a promising integrative adjunct in modern dentistry, warranting further controlled clinical trials to define optimal formulations, dosages, and long-term outcomes.

Keywords: lavender oil, gingival inflammation, oral infections, dental anxiety, antimicrobial activity, integrative dentistry

1. Biological and Pharmacological Basis of Lavender Oil in Oral Pathology

Lavender essential oil (LEO), derived predominantly from *Lavandula angustifolia*, has gained increasing scientific attention in oral medicine due to its multifactorial biological activity encompassing antimicrobial, anti-inflammatory, antioxidant, and neuromodulator effects. Experimental data demonstrate that LEO exhibits a broad-spectrum antimicrobial action against

key oral pathogens, including *Candida albicans*, *Streptococcus mutans*, and *Staphylococcus aureus*, while also reducing microbial adherence to denture base resins, highlighting its relevance in prosthetic-associated infections and denture stomatitis [1].

Beyond its antimicrobial properties, lavender oil has been shown to exert measurable systemic and autonomic effects. Inhalational exposure to LEO significantly influences vital parameters and anxiety-related physiological responses, suggesting a neurovegetative modulation that may indirectly impact oral inflammatory status via stress-related pathways [2]. These effects are particularly relevant in oral inflammatory diseases, where psychological stress is known to exacerbate gingival inflammation and impair immune regulation.

At the cellular level, LEO demonstrates pronounced antioxidant activity. Comparative clinical investigations in recurrent aphthous ulceration indicate that lavender oil reduces oxidative stress markers and accelerates mucosal healing, underscoring the role of redox balance in oral mucosal pathology [3]. Additionally, its topical analgesic effect, documented in vivo prior to dental anaesthesia, suggests peripheral modulation of nociceptive pathways, which may further contribute to inflammation control by limiting neurogenic inflammation [4].

The anxiolytic properties of lavender oil have been extensively documented in dental settings. Systematic analyses confirm that aromatherapy with LEO significantly reduces dental anxiety, a factor closely linked to altered salivary composition, immune suppression, and increased susceptibility to periodontal disease [5]. However, despite its therapeutic promise, essential oils are not devoid of adverse reactions, as occupational contact dermatitis has been reported, emphasizing the need for controlled dosing and standardized formulations in oral applications [6].

From a pharmacological perspective, LEO has been recognized as a valuable bioactive compound in chronic wound management due to its combined antimicrobial and anti-inflammatory actions, mechanisms directly translatable to chronic gingival and periodontal lesions [7]. In vitro studies further demonstrate that lavender oil can act synergistically with conventional antimicrobial agents, enhancing efficacy while potentially reducing required drug concentrations and associated side effects [8].

The psychophysiological dimension of lavender oil is particularly relevant in paediatric and adult dentistry. Comparative clinical trials reveal that LEO aromatherapy significantly lowers dental anxiety in children, improving cooperation and potentially reducing stress-induced inflammatory responses in the oral cavity [9]. These clinical observations are supported by mechanistic studies showing that lavender oil modulates macrophage activity, downregulating pro-inflammatory cytokines such as TNF- α and IL-6, while preserving cellular viability, a key feature for maintaining periodontal tissue homeostasis [10].

Importantly, experimental models indicate that the anxiolytic effects of lavender oil are not solely dependent on olfactory perception. Animal studies demonstrate preserved anxiolytic responses even in anosmic conditions, suggesting systemic absorption and central nervous system activity independent of olfactory pathways [11]. This finding broadens the therapeutic relevance of lavender oil beyond aromatherapy alone.

Complementary investigations confirm that LEO possesses significant antioxidant, analgesic, and anti-inflammatory properties, acting through modulation of cyclooxygenase pathways, free radical scavenging, and inhibition of inflammatory mediators [12]. These pharmacodynamic characteristics support its application in inflammatory oral conditions characterized by oxidative stress and pain.

Clinical formulations of lavender oil have also been evaluated systemically. Oral administration of standardized lavender oil preparations has shown efficacy comparable to inhalational routes in improving sleep quality, a factor indirectly associated with immune

competence and oral inflammatory regulation [13]. Similarly, intranasal administration has been linked to reduced salivary cortisol levels, reinforcing the connection between stress modulation and oral health [14].

In the context of dentistry, essential oils, including lavender, have been comprehensively reviewed for their therapeutic properties, with particular emphasis on antimicrobial and anti-inflammatory mechanisms relevant to gingival and periodontal diseases [15]. Recent biomaterial research further demonstrates that incorporating LEO into chitosan-based sponges enhances antibacterial activity while preserving physical integrity, suggesting promising applications in haemostatic and regenerative oral materials [16].

The interaction between essential oils and the oral microbiome represents an emerging field. Lavender oil has been shown to modulate microbial composition without inducing dysbiosis, supporting a more balanced ecological approach to infection control [17]. Advanced pharmaceutical developments, such as oromucosal sprays containing plant-derived compounds including LEO, further validate its role in managing infectious and inflammatory oral conditions [18].

At the material science level, LEO has been successfully integrated into hydroxyapatite-based composites, demonstrating sustained antimicrobial activity, relevant for implantology and restorative dentistry [19]. Its systemic calming effects have also been corroborated in non-dental clinical environments, reinforcing the robustness of its anxiolytic profile [20].

Finally, comprehensive reviews highlight the role of lavender oil in wound healing through enhanced angiogenesis, collagen deposition, and inflammation resolution, mechanisms directly applicable to periodontal regeneration and post-surgical oral healing [21]. These observations are consistent with earlier foundational studies that established the broad biological activity of lavender essential oil, forming the basis for its current and future applications in oral pathology [22].

2. Experimental and In Vitro Evidence Supporting Antimicrobial and Anti-Inflammatory Efficacy

Experimental and in vitro investigations provide robust mechanistic support for the antimicrobial and anti-inflammatory potential of *Lavandula angustifolia* essential oil (LEO) in oral pathology. One of the most consistently reported effects is its direct antimicrobial activity against representative oral pathogens. Controlled laboratory studies demonstrate that LEO significantly inhibits the growth of *Candida albicans*, *Streptococcus mutans*, and *Staphylococcus aureus*, microorganisms strongly implicated in denture-related infections, dental caries, and opportunistic oral infections [1]. Importantly, beyond planktonic inhibition, LEO reduces microbial adhesion to acrylic denture base resins, indicating a capacity to interfere with early biofilm formation rather than acting solely as a bactericidal agent [1].

Synergistic antimicrobial interactions represent a key experimental finding. In vitro assays reveal that LEO enhances the efficacy of conventional antimicrobial agents when used in combination, producing additive or synergistic effects against both Gram-positive bacteria and fungi [8]. This property is clinically relevant, as it supports the potential use of lavender oil as an adjunctive therapy capable of lowering antimicrobial doses and mitigating resistance development, a growing concern in oral infection management [15].

Anti-inflammatory activity has been extensively characterized at the cellular level. Experimental models using THP-1 macrophages demonstrate that LEO significantly downregulates pro-inflammatory cytokines, including tumor necrosis factor- α and interleukin-6, while preserving cellular viability and metabolic activity [10]. These findings indicate that

lavender oil exerts a modulatory, rather than cytotoxic, effect on immune cells, a critical requirement for maintaining periodontal tissue homeostasis. Complementary antioxidant assays further show that LEO reduces oxidative stress markers, supporting its role in limiting inflammation-driven tissue damage in oral mucosa [3,12].

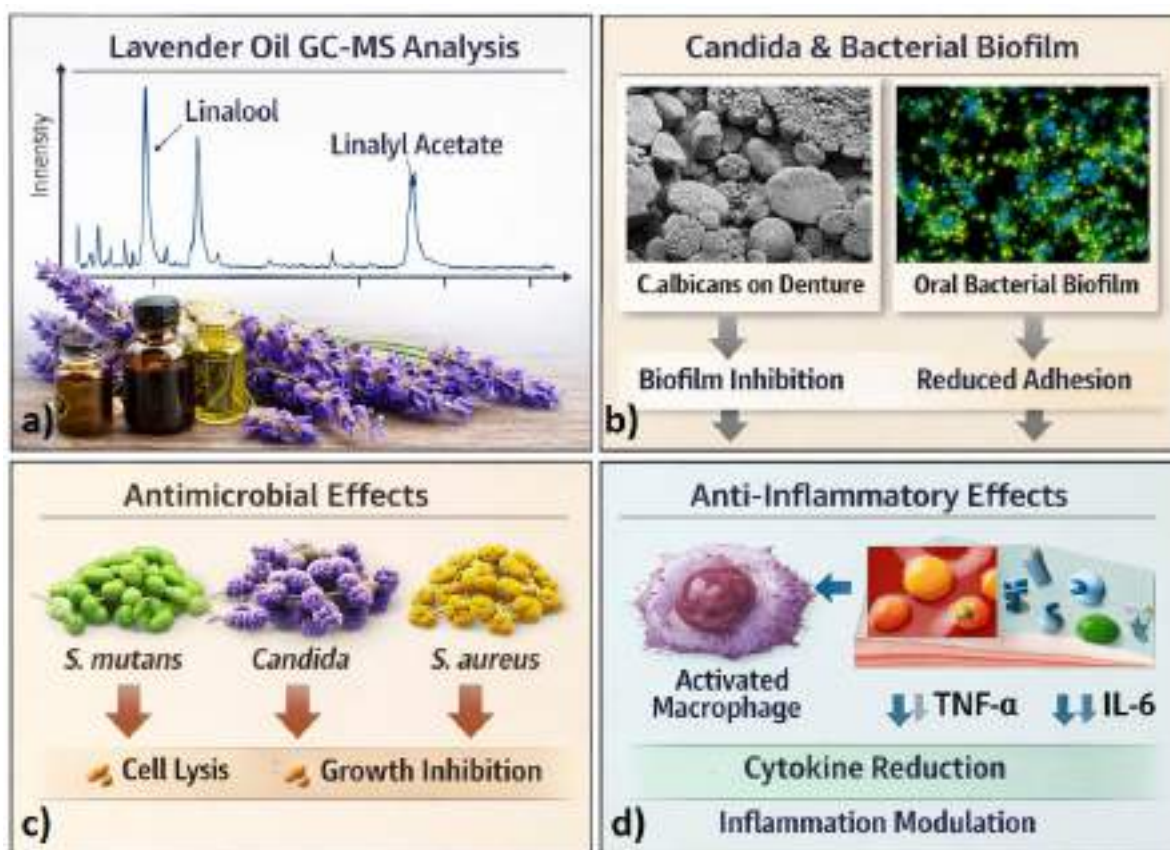


Figure 1. Biological mechanisms underlying the antimicrobial and anti-inflammatory effects of *Lavandula angustifolia* essential oil in oral pathology

Figure 1 illustrates the principal experimental mechanisms through which *Lavandula angustifolia* essential oil exerts therapeutic effects relevant to oral diseases. Panel (a) depicts the characteristic GC–MS profile of lavender oil, highlighting linalool and linalyl acetate as major bioactive constituents. Panel (b) shows the inhibitory effect on *Candida albicans* colonization and oral bacterial biofilm formation, with reduced microbial adhesion to prosthetic surfaces. Panel (c) summarizes the antimicrobial activity against key oral pathogens (*Streptococcus mutans*, *Candida* spp., *Staphylococcus aureus*), resulting in cell lysis and growth inhibition. Panel (d) illustrates the anti-inflammatory action mediated through macrophage modulation, with decreased production of pro-inflammatory cytokines (TNF- α , IL-6), contributing to inflammation control and tissue homeostasis in the oral cavity.

Material-based experimental approaches have expanded the applicability of lavender oil in dentistry. Incorporation of LEO into chitosan sponges and polymeric matrices results in enhanced antibacterial activity without compromising mechanical or structural properties, suggesting suitability for local delivery systems in oral surgery and wound management [16]. Similar outcomes have been reported for hydroxyapatite-based composites enriched with lavender oil, which exhibit sustained antimicrobial activity relevant for restorative and implant-associated applications [19].

In vitro microbiome-oriented studies further indicate that LEO exerts selective antimicrobial effects without inducing broad dysbiosis. Instead, it appears to modulate microbial equilibrium, favoring a less pathogenic oral environment [17]. This ecological perspective differentiates lavender oil from conventional antiseptics, which often exert non-selective antimicrobial pressure.

3. Clinical Applications of Lavender Oil in Dentistry

Clinical investigations support the translational relevance of *Lavandula angustifolia* essential oil (LEO) in dentistry, particularly in the management of gingival inflammation, oral infections, pain control, and patient-related psychophysiological responses. One of the most clinically substantiated applications of LEO is its antimicrobial use in prosthetic and mucosal pathology. Studies demonstrate a reduction in microbial colonization and adherence on denture base materials, with efficacy against *Candida albicans* and cariogenic bacteria, supporting its use in denture stomatitis prevention and adjunctive hygiene protocols [1,15].

In inflammatory oral conditions, topical application of lavender oil has shown beneficial effects through its combined anti-inflammatory and antioxidant mechanisms. Clinical data from patients with recurrent aphthous ulceration indicate accelerated lesion resolution and symptomatic relief, suggesting improved mucosal healing and modulation of inflammatory mediators [3,12]. These effects are particularly relevant for gingival inflammation, where oxidative stress and immune dysregulation play central pathogenic roles.

Pain management represents another clinically relevant domain. In vivo studies evaluating topical lavender oil application prior to dental anaesthesia report significantly reduced pain perception, highlighting its potential role as a non-pharmacological adjunct for procedural comfort [4]. This analgesic effect may contribute indirectly to inflammation control by attenuating stress-induced neurogenic inflammatory responses.

The anxiolytic properties of lavender oil have been extensively validated in dental practice. Randomized clinical trials and systematic reviews consistently demonstrate reductions in dental anxiety and improvements in patient cooperation following lavender oil aromatherapy, both in adult and paediatric populations [5,9]. Given the established association between psychological stress, altered salivary composition, and increased susceptibility to periodontal inflammation, anxiety reduction represents a clinically meaningful indirect pathway through which LEO may influence oral inflammatory status.

Systemic and local delivery routes have both been explored clinically. Oral and intranasal administration of standardized lavender oil formulations has been associated with reduced salivary cortisol levels, improved sleep quality, and stabilization of vital signs, all of which contribute to enhanced immune function and tissue repair capacity in the oral cavity [13,14,20]. Importantly, these effects appear to persist even in the absence of olfactory perception, suggesting pharmacological activity beyond aromatherapeutic mechanisms [11].

From a safety perspective, clinical use of lavender oil is generally well tolerated; however, reports of contact dermatitis underscore the necessity for standardized concentrations and cautious application, particularly in patients with known sensitivities [6]. In biomaterial-based clinical applications, the incorporation of LEO into chitosan sponges and wound dressings has demonstrated favourable antibacterial and haemostatic properties, supporting its potential role in oral surgery and post-extraction care [16,21].

Finally, comprehensive clinical reviews highlight the expanding role of essential oils in dentistry, positioning lavender oil as a multifunctional agent capable of addressing the microbial, inflammatory, and psychophysiological components of oral disease [15,17,22].

Collectively, current clinical evidence supports the adjunctive use of lavender oil in dentistry, while highlighting the need for standardized protocols and larger controlled trials to optimize its therapeutic integration.

Table 1 summarizes the core biological and clinical effects of *Lavandula angustifolia* essential oil relevant to dentistry. Reference numbers correspond strictly to the provided bibliography.

Table 1. Core Biological and Clinical Effects of *Lavandula angustifolia* Essential Oil in Dentistry

Domain	Model / Context	Key effects	Clinical relevance	Ref.
Antimicrobial activity	In vitro, denture materials	Inhibits oral bacteria and Candida; reduces adhesion	Control of biofilm and prosthetic infections	[1,8,15]
Anti-inflammatory and antioxidant effects	Cellular and clinical models	Decreases pro-inflammatory cytokines and oxidative stress	Gingival inflammation and mucosal healing	[3,10,12]
Analgesic and anxiolytic effects	Clinical dental studies	Reduces pain and dental anxiety	Improved patient comfort and compliance	[4,5,9]
Neuroendocrine modulation	Clinical trials	Lowers salivary cortisol; improves sleep	Stress-related immune regulation	[13,14,20]
Biomaterial integration	Experimental material studies	Enhances antibacterial properties of bioactive matrices	Oral surgery and regenerative applications	[16,19,21]
Safety profile	Clinical reports	Occasional contact dermatitis	Need for standardized dosing	[6]

4. Psychophysiological Implications and Future Perspectives

The psychophysiological effects of *Lavandula angustifolia* essential oil (LEO) represent a critical yet often underestimated component of its therapeutic relevance in dentistry. Psychological stress and anxiety are well-established modulators of immune function, inflammatory responses, and wound healing within the oral cavity. Clinical and experimental evidence indicates that LEO exerts significant anxiolytic and autonomic regulatory effects, which may indirectly influence gingival inflammation and susceptibility to oral infections [2,5].

Randomized clinical trials demonstrate that inhalational exposure to lavender oil leads to measurable reductions in anxiety scores and stabilization of vital signs, including heart rate and blood pressure, reflecting parasympathetic activation and attenuation of stress-induced sympathetic responses [2,20]. In dental settings, these effects translate into improved patient cooperation, reduced procedural stress, and potentially diminished neurogenic inflammation, a contributor to periodontal tissue breakdown [5,9]. Systematic reviews further support the consistency of these findings across diverse clinical contexts, reinforcing the robustness of lavender oil's anxiolytic profile [5].

At the neuroendocrine level, lavender oil has been shown to modulate hypothalamic–pituitary–adrenal (HPA) axis activity. Clinical studies report significant reductions in salivary cortisol following intranasal or inhalational administration of LEO, indicating effective stress hormone regulation [14]. Given that elevated cortisol levels are associated with impaired immune surveillance, delayed wound healing, and increased periodontal inflammation, this endocrine modulation provides a plausible mechanistic link between psychological relaxation and improved oral inflammatory outcomes.

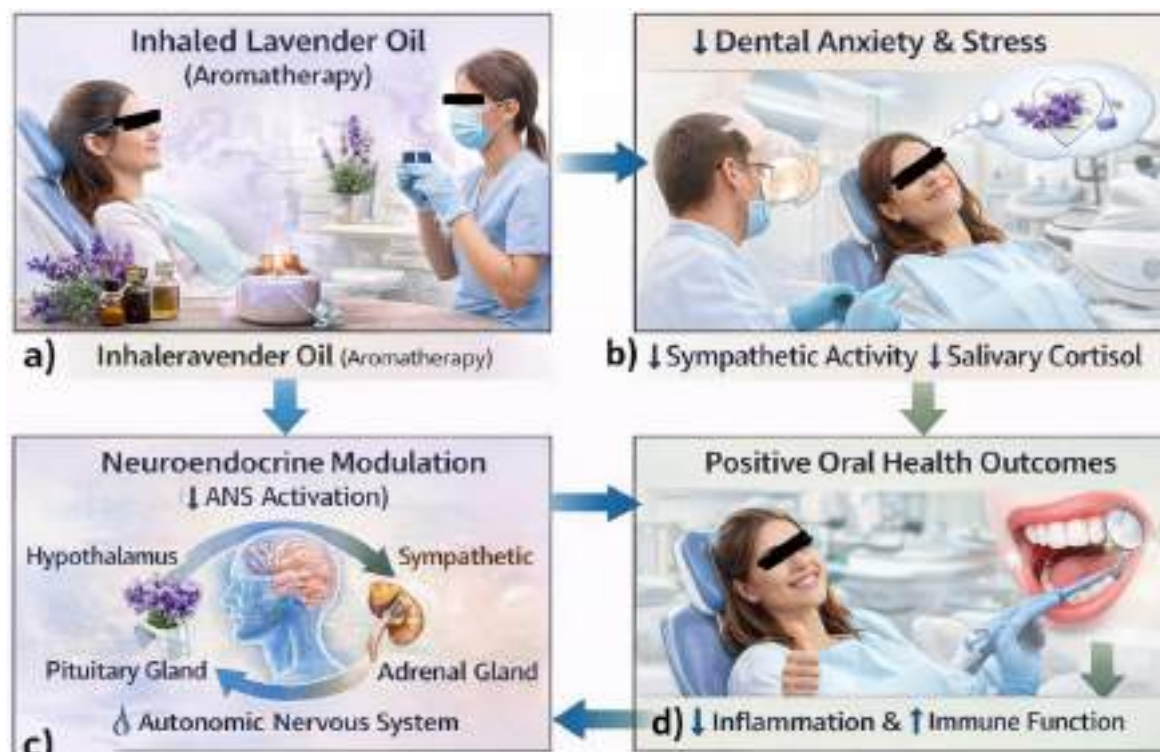


Figure 2. Psychophysiological pathways linking inhaled *Lavandula angustifolia* essential oil to oral health outcomes

Figure 2 illustrates the sequential psychophysiological mechanisms through which inhaled *Lavandula angustifolia* essential oil influences oral health in dental settings. Panel (a) depicts aromatherapeutic exposure during dental treatment. Panel (b) shows the reduction of dental anxiety and stress, associated with decreased sympathetic nervous system activity and lower salivary cortisol levels. Panel (c) highlights neuroendocrine modulation via the hypothalamic–pituitary–adrenal axis and autonomic nervous system regulation. Panel (d) summarizes the downstream effects on oral health, including reduced inflammatory burden and enhanced immune function, supporting improved tissue healing and inflammatory control in the oral cavity.

Importantly, experimental animal models reveal that the anxiolytic effects of lavender oil persist even in the absence of olfactory input, suggesting systemic absorption and central nervous system activity beyond classical aromatherapy pathways [11]. This observation broadens the therapeutic framework of LEO, supporting its classification as a bioactive phytopharmaceutical rather than a purely sensory intervention. Such findings are consistent with clinical evidence demonstrating comparable efficacy between inhaled and orally administered standardized lavender oil preparations in improving sleep quality and stress-related outcomes [13].

The relationship between psychophysiological regulation and oral immunity is further reinforced by the documented anti-inflammatory and antioxidant properties of lavender oil. By reducing oxidative stress and inflammatory mediator release at the cellular level, LEO may counteract the deleterious effects of chronic stress on periodontal tissues and oral mucosa

[3,10,12]. This bidirectional interaction between psychological state and local inflammatory control positions lavender oil as a uniquely integrative adjunct in oral healthcare.

Looking forward, future research should prioritize the standardization of lavender oil formulations, dosages, and delivery routes to ensure reproducibility and safety in clinical practice. Although current evidence supports its efficacy, reports of contact dermatitis and hypersensitivity reactions highlight the necessity for rigorous pharmacovigilance and patient selection [6]. Advances in biomaterial science offer promising avenues for controlled local delivery, as demonstrated by the incorporation of LEO into chitosan sponges and bioactive dressings with sustained antimicrobial and anti-inflammatory effects [16,21].

Emerging studies on the oral microbiome suggest that lavender oil may exert a modulatory, rather than disruptive, influence on microbial ecosystems, aligning with contemporary ecological approaches to oral disease management [17]. Integration of LEO into oromucosal sprays, polymeric carriers, and composite biomaterials further expands its clinical applicability while minimizing systemic exposure [18,19].

The psychophysiological implications of lavender oil extend beyond symptomatic anxiety reduction, encompassing neuroendocrine regulation, immune modulation, and enhanced tissue healing. Future clinical trials with larger sample sizes, standardized protocols, and combined biological–psychological endpoints are essential to fully elucidate the role of lavender oil as an evidence-based adjunct in modern dentistry [15,22].

Conclusions

Collectively, the available experimental and clinical evidence indicates that *Lavandula angustifolia* essential oil represents a multifunctional adjunct in oral healthcare. Its antimicrobial, anti-inflammatory, antioxidant, analgesic, and anxiolytic properties converge on key pathogenic mechanisms involved in gingival inflammation, oral infections, and impaired wound healing. Importantly, lavender oil demonstrates efficacy against representative oral pathogens while simultaneously modulating host immune and stress responses, offering a dual biological and psychophysiological therapeutic profile that is particularly relevant in contemporary, patient-centered dental practice, within both preventive and adjunctive therapeutic strategies across diverse clinical contexts worldwide today.

Nevertheless, despite promising findings, current evidence highlights the necessity for further high-quality, standardized clinical trials to optimize the integration of lavender oil into routine dental care. Future research should focus on dose standardization, formulation stability, long-term safety, and well-defined clinical endpoints, particularly in periodontal and peri-implant conditions. In parallel, advances in biomaterial science and controlled-release systems may enhance local efficacy while minimizing adverse reactions. Integrating psychophysiological outcomes with biological markers will be essential to fully capture the therapeutic scope of lavender oil and to support its evidence-based adoption within modern integrative dentistry. Such efforts may facilitate guideline development and responsible clinical implementation worldwide in oral medicine practice and research settings.

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HOST–CANDIDA INTERACTIONS IN ORAL CANDIDIASIS: FROM EPITHELIAL RESPONSE TO IMMUNE EVASION

University Teaching Assistant, Ph.D. Student Cristian COJOCARIU¹; University Teaching Assistant, Ph.D. Student Mioara DÂRNEA²; University Teaching Assistant, PhD Student Alexandra Camelia POGĂCIAN-MAIER³; University Teaching Assistant, PhD Student Dorin Ioan COCOȘ¹; Associate Professor, PhD Ramona Diana FEIER⁴; Professor, Ph.D. Kamel EARAR¹.

¹Faculty of Dental Medicine, “Dunărea de Jos” University, 800008 Galați, Romania;

²Department of Implantology, Removable Protheses, Dental Protheses Technology, “Grigore T. Popa” University of Medicine and Pharmacy, 16 Universității Street, 700115 Iași, Romania;

³Doctoral School, University of Medicine and Pharmacy “Iuliu Hatieganu” Cluj-Napoca, 400347 Cluj-Napoca, Romania;

⁴Department of Dentistry, Faculty of Medicine, Dimitrie Cantemir University of Târgu Mureș, 540545 Târgu Mureș, România

Authors correspondents: Dorin Ioan COCOȘ: cdorin1123@gmail.com; Ramona Diana FEIER: dr.ramonafeier@yahoo.ro

Abstract

Oral candidiasis represents a dynamic clinical manifestation of disrupted host–microbe equilibrium, in which *Candida albicans* transitions from a commensal organism to an invasive pathogen under conditions of compromised local or systemic immunity. This paper explores the multilayered interactions between the oral epithelium and *C. albicans*, emphasizing epithelial sensing mechanisms, immune activation, and fungal strategies of immune evasion. We examine how epithelial cells function as an active immunological interface, integrating fungal morphotype and burden to discriminate between tolerable colonization and pathogenic invasion, primarily through MAPK and NF-κB signalling pathways and the release of pro-inflammatory cytokines and antimicrobial peptides. Central to mucosal defense is the IL-17 axis, which coordinates neutrophil recruitment, epithelial amplification, and sustained adaptive Th17 responses to promote fungal clearance while preserving mucosal integrity. The review further highlights the sophisticated immune-evasion repertoire of *C. albicans*, including cell-wall remodelling, candidalysin-mediated tissue damage, hydrolytic enzyme production, and biofilm formation, particularly in denture-associated environments. Finally, we discuss the clinical implications of these mechanisms and emerging therapeutic directions that shift from purely antifungal approaches toward anti-virulence strategies, biofilm disruption, host-directed immunomodulation, and microbiome-informed interventions. Understanding these host–pathogen dynamics provides a mechanistic framework for risk stratification, prevention, and more durable management of oral candidiasis.

Keywords: oral candidiasis; *Candida albicans*; epithelial immunity; IL-17 axis; immune evasion

1. Epithelial Sensing and Frontline Responses in the Oral Cavity

Candida albicans is a frequent commensal of the oral cavity, yet it can rapidly shift to a pathogenic phenotype when local or systemic host defences are impaired (e.g., xerostomia, antibiotic exposure, diabetes, immunosuppression, denture wearing) [3,6]. The oral epithelium

is not a passive barrier; it acts as an immunologically competent interface that detects fungal invasion and initiates antifungal programs. A critical determinant of pathogenicity is *C. albicans* morphogenesis: the yeast-to-hypha transition correlates with epithelial invasion, tissue damage, and robust inflammatory signalling [8].

Oral epithelial recognition integrates fungal burden, morphotype, and cell-wall exposure patterns. Commensal-level colonization tends to induce a restrained epithelial response, supporting mucosal homeostasis and limiting unnecessary inflammation [1,5]. In contrast, hyphal growth triggers strong activation of epithelial MAPK and NF- κ B pathways, amplifying transcription of inflammatory mediators and antimicrobial effectors [1,8]. The hypha-associated toxin candidalysin is a key driver of epithelial damage and danger signalling, promoting cytokine and chemokine release that shapes early antifungal immunity [8].

Activated oral keratinocytes secrete IL-1 family cytokines and IL-6, alongside neutrophil-recruiting chemokines, creating a rapid inflammatory gradient that mobilizes professional phagocytes to the site of infection [1,5]. In parallel, epithelial antimicrobial peptides (e.g., β -defensins, cathelicidin) contribute to fungal growth restriction and help stabilize barrier function [1,5]. This epithelial-immune crosstalk is clinically relevant: impaired epithelial integrity or reduced salivary antimicrobial activity (common in xerostomia) lowers the threshold for symptomatic oral candidiasis [3,5,6].

Beyond direct antifungal activity, the epithelium orchestrates immunological “triage”: it tolerates low-level fungal presence while responding aggressively to invasive hyphae, thereby maintaining colonization–infection equilibrium. When this equilibrium fails, epithelial activation becomes a gateway to sustained inflammation and symptomatic disease [5].

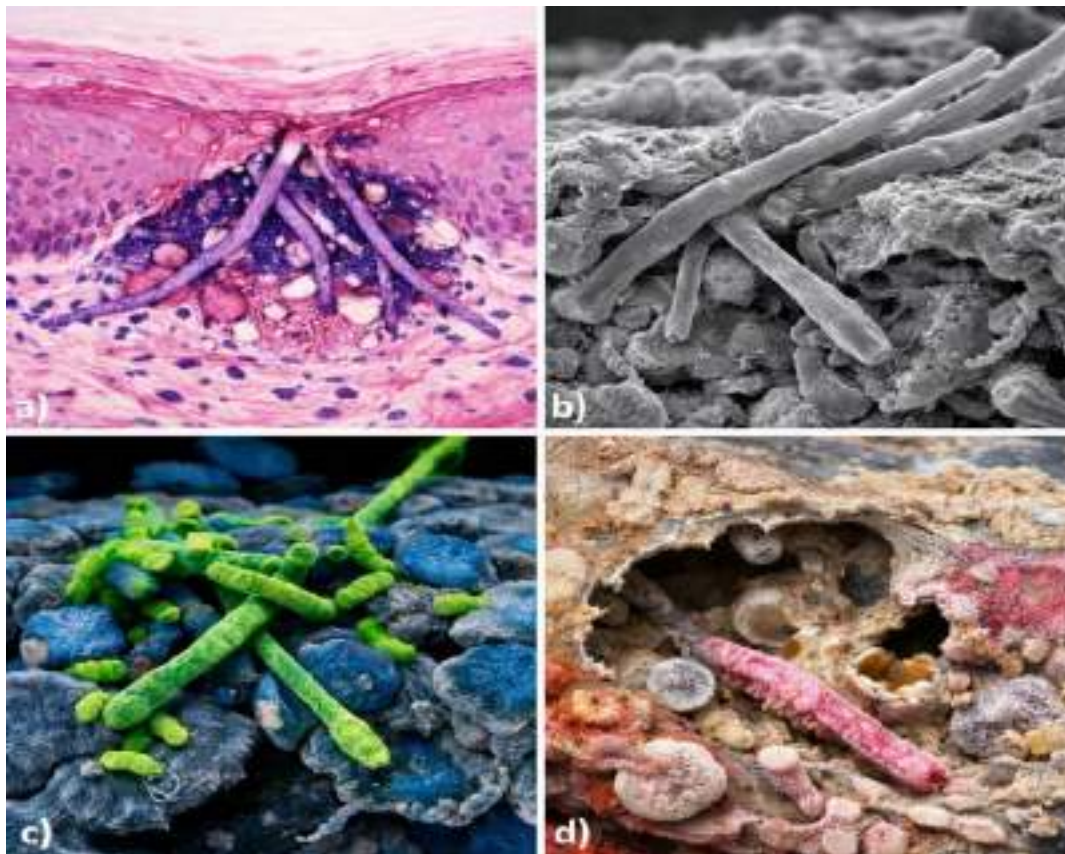


Figure 1. Epithelial–*Candida albicans* interactions in oral mucosa: morphological and ultrastructural evidence of invasion and damage

In Figure 1. Multimodal microscopic representation of *Candida albicans* interaction with the oral epithelium. (a) Histological section (H&E/PAS) showing hyphal penetration through stratified squamous epithelium, associated with focal epithelial disruption and inflammatory cell infiltrate. (b) Scanning electron microscopy (SEM) image highlighting hyphal elements invading the epithelial surface and intercellular spaces. (c) Fluorescence microscopy illustrating adherent and invasive *Candida albicans* cells (green) in close contact with epithelial structures (blue), emphasizing fungal–host interface dynamics. (d) High-resolution SEM image depicting advanced tissue damage, extracellular matrix disruption, and fungal persistence within a damaged epithelial niche, consistent with biofilm-associated pathogenicity.

2. Innate and Adaptive Immunity: IL-17 Axis as the Mucosal “Command Center”

Oral anti-*Candida* immunity relies on rapid innate containment followed by adaptive reinforcement. Neutrophils are the dominant early effector cell population in oral candidiasis; their recruitment is driven by epithelial chemokines and IL-17-dependent signaling. Neutrophils exert candidacidal activity via phagocytosis, oxidative and non-oxidative mechanisms, and extracellular antimicrobial components [1,5]. Clinical parallels are consistent: neutropenia or neutrophil dysfunction increases susceptibility to mucosal and systemic *Candida* disease.

The most decisive immunological pathway in mucosal candidiasis is the IL-17 network. IL-17 stimulates epithelial and stromal cells to produce neutrophil-attracting chemokines and granulopoiesis factors, while also enhancing antimicrobial peptide production at the mucosal surface [7]. This functional triad — neutrophil recruitment, epithelial amplification, antimicrobial induction — explains why IL-17 blockade (therapeutic or genetic) predisposes to oral candidiasis [5,7].

Adaptive Th17 responses provide sustained IL-17 production, supporting mucosal clearance and limiting recurrence [7]. Th1 immunity contributes by activating phagocyte candidacidal programs and shaping antifungal cytokine profiles, but IL-17 remains central in oral mucosal defense [5,7]. Importantly, the oral cavity is not immunologically sterile; it contains a complex microbial ecosystem, and effective antifungal defense must be potent yet spatially and temporally controlled to avoid collateral epithelial injury and dysbiosis [6].

Excess or prolonged inflammation can destabilize mucosal tolerance and create permissive niches for recurrent infection, particularly in denture-associated microenvironments [3,6].

3. Immune Evasion by *Candida*: from Stealth Cell Walls to Immune Modulation

The success of *C. albicans* as an opportunistic pathogen reflects a layered immune-evasion repertoire that targets recognition, effector function, and tissue-level clearance. A foundational mechanism is cell-wall remodelling during hyphal transition, which can reduce immune visibility by altering exposure of immunostimulatory wall components. This “stealth” phenotype delays efficient recognition and can dampen early antifungal responses, facilitating mucosal persistence [1,5].

Hyphal invasion is not only mechanically disruptive; it increases tissue damage and creates microenvironments where immune access becomes less effective. Candidalysin-mediated epithelial injury amplifies inflammation, yet paradoxically may also promote immune dysregulation if damage-driven inflammation becomes excessive or chronic [8]. In addition, *C. albicans* produces hydrolytic enzymes (including proteases) that support invasion and can interfere with host defense proteins, contributing to tissue penetration and immune escape [3,5].

A clinically dominant evasion platform is biofilm formation, especially on dentures and acrylic surfaces. Biofilms provide mechanical shielding, increase tolerance to antifungals, and restrict immune penetration and phagocyte efficiency. Biofilm-associated oral candidiasis is therefore characterized by persistence, frequent relapse, and treatment refractoriness unless local factors (prosthesis hygiene, nocturnal denture removal, mucosal trauma) are addressed alongside antifungal therapy [3,6].

Beyond physical barriers, *Candida* can modulate host immune signaling by skewing inflammatory pathways and altering cytokine balance, contributing to ineffective clearance or “tolerant inflammation” that sustains colonization while maintaining symptomatic mucositis [1,5]. The net clinical consequence is a pathogen that can survive in the oral cavity despite immunological pressure, particularly when host defenses are systemically weakened or locally disrupted.

4. Clinical Translation and Emerging Therapeutic Directions

Oral candidiasis is best understood as the clinical endpoint of a disrupted host–microbe equilibrium. Predisposing conditions (immunosuppression, metabolic disease, antibiotics, xerostomia, dentures) lower the ecological threshold for transition from commensalism to invasion [3,6]. Mechanistically, failure can occur at multiple levels: reduced epithelial barrier integrity, impaired neutrophil recruitment/function, compromised IL-17 signaling, or biofilm-protected fungal persistence [5,7]. This mechanistic stratification has direct implications for management.

Conventional therapy (topical polyenes/azoles; systemic azoles for extensive disease) remains effective in many cases. However, relapse is common when risk factors persist, and biofilm-associated disease often requires adjunctive measures targeting the ecological niche (prosthesis disinfection, mechanical biofilm disruption, xerostomia management) [3,6]. From a mechanistic standpoint, successful long-term control frequently depends less on escalating antifungal potency and more on restoring mucosal homeostasis.

Emerging strategies increasingly focus on:

- anti-virulence approaches (attenuating hyphal transition and candidalysin-related damage),
- biofilm disruption (reducing matrix protection and improving immune/drug penetration),
- host-directed therapy (strengthening mucosal defense pathways, particularly IL-17–epithelial effector loops), and
- microbiome-informed interventions (supporting bacterial–fungal balance to prevent pathogenic overgrowth) [1,5,6,7,8].

In high-risk populations — patients on IL-17-targeting biologics, advanced immunosuppression, severe xerostomia — prophylactic and preventive strategies become especially relevant, because the immunological bottleneck is predictable: reduced IL-17-driven mucosal protection predisposes specifically to mucocutaneous *Candida* disease [5,7]. Future therapeutics should therefore be risk-stratified and mechanism-guided, combining antifungal agents with ecological and host-modulating interventions to reduce recurrence and limit chronic inflammation.

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INNOVATIVE CLINICAL COMMUNICATION AND COUNSELING TECHNIQUES FOR EDENTULOUS PSYCHIATRIC PATIENTS

University Teaching Assistant, Ph.D. Student Mioara DÂRNEA¹; University Teaching Assistant, Ph.D. Student Cristian COJOCARIU²; Associate Professor, Ph.D. Sorina-Mihaela BĂLAN³; Associate Professor, Ph.D. Carmen GÂLEA³; Associate Professor, Ph.D. Ramona Diana FEIER³; Prof. Univ. Habil. Ph.D. Roxana-Ionela VASLUIANU⁴

¹Department of Implantology, Removable Protheses, Dental Protheses Technology, "Grigore T. Popa" University of Medicine and Pharmacy, 16 Universității Street, 700115 Iași, Romania;

²Faculty of Dental Medicine, "Dunărea de Jos" University, 800008 Galați, Romania;

³Department of Dentistry, Faculty of Medicine, Dimitrie Cantemir University of Târgu Mureș, 540545 Târgu Mureș, România;

⁴Department of Implantology, Removable Protheses, Dental Protheses Technology, "Grigore T. Popa" University of Medicine and Pharmacy, 16 Universității Street, 700115 Iași, Romania

Author correspondent: Mioara DÂRNEA: miodar2@yahoo.com

Abstract

Patients with mental disorders represent a vulnerable group in prosthodontic rehabilitation, frequently experiencing severe oral disease, premature tooth loss, and limited access to consistent dental care. Removable denture therapy in this population is often complicated by cognitive impairment, anxiety, reduced cooperation, medication-induced xerostomia, and poor long-term compliance. Contemporary prosthodontics emphasizes that psychiatric illness is not a contraindication for treatment but rather a condition requiring individualized clinical adaptation. Advanced approaches include multidisciplinary planning, modified appointment structures, and selective use of sedation or general anesthesia when conventional care is not feasible. Innovations in materials, such as soft liners, flexible thermoplastic bases, and high-impact acrylics, enhance comfort and reduce mucosal trauma, particularly in patients with impaired pain communication. Implant-assisted overdentures may offer improved retention in carefully selected cases, while CAD/CAM digital workflows reduce chairside time and minimize adjustment needs. Psychological strategies, including behavioral desensitization, caregiver involvement, and trust-building communication, are essential for successful adaptation. Long-term success depends on simplified hygiene protocols, structured recalls, and coordinated institutional support. Ultimately, advanced removable denture therapy contributes not only to oral function and aesthetics but also to nutrition, social integration, and overall quality of life in patients with mental disorders.

Keywords: removable dentures, mental disorders, prosthodontic rehabilitation, special needs dentistry

1. Introduction

Patients with mental disorders often face unique challenges in oral healthcare, resulting in significantly worse oral health outcomes compared to the general population [1]. Severe mental

illnesses such as schizophrenia, bipolar disorder, and major depression are associated with higher rates of tooth decay, periodontal disease, and edentulism (complete tooth loss) [1].

For example, one meta-analysis found that individuals with severe mental illness had nearly 3 times the odds of having lost all their teeth compared to the general population [1].

Similarly, adults with intellectual disabilities experience tooth loss at younger ages and more frequently remain without prosthetic replacements; over one-third of older adults with intellectual disabilities in an Irish study were edentulous, and 60% of those had no dentures to restore function [2].

Historically, dental care for patients with mental or developmental disorders was often neglected or limited to emergency-driven interventions, a phenomenon sometimes called the “halo effect” where providers focused solely on the primary psychiatric condition [3]. This led to infrequent preventive care and a reliance on extracting diseased teeth under general anesthesia (GA) rather than attempting restorative treatments [3].

Contemporary approaches, however, emphasize that mental illness in itself is not a contraindication to dental therapy. With appropriate modifications and advanced techniques, removable denture therapy can be successfully provided to these patients, improving their quality of life and even contributing positively to their mental health and cognitive function [4] [5]. In this article, we outline advanced approaches in planning and delivering removable prostheses for patients with mental disorders, covering clinical adaptations, materials innovations, psychological management, and strategies to enhance compliance.

2. Individualized Treatment Planning and Modifications in Care

Effective rehabilitation with removable dentures in patients who have mental disorders begins with meticulous treatment planning tailored to the individual’s capabilities and health status. A thorough pretreatment assessment is essential, ideally involving a multidisciplinary team (dentist, physician/psychiatrist, anesthesiologist, and caregivers). Medical history and current medications should be reviewed for factors that impact oral health – for instance, many psychotropic medications (antipsychotics, antidepressants) cause xerostomia (dry mouth), which elevates caries risk and can affect denture retention. Planning should account for preventive measures like topical fluoride or salivary substitutes to mitigate these effects [1].

One of the first decisions in planning is determining the appropriate treatment setting and use of adjunctive sedation or anesthesia. Patients with severe intellectual disability, autism spectrum disorder (ASD), advanced dementia, or severe psychiatric symptoms may not tolerate conventional dental visits. In such cases, advanced planning might involve performing multiple procedures in a single session under deep sedation or general anesthesia. Studies show that a vast majority of special-needs patients treated under GA require invasive interventions; for example, in one retrospective analysis, 86% of special-needs patients undergoing GA had multiple teeth extractions performed in that session [6]. Combining necessary extractions with immediate denture fabrication can be considered to avoid leaving the patient edentulous after surgery. An immediate denture (placed at the time of extractions) can provide continuous function and psychosocial benefit, though it requires careful prior impressions and an adaptable plan since an exact fit may need post-insertion adjustments.

Each patient’s tolerance and understanding of procedures will dictate modifications to standard protocols. Shorter, more frequent appointments may be preferable for some patients to accommodate limited attention spans or high anxiety. Alternatively, for those who struggle with any clinical visits, a one-step denture technique or accelerated workflow can minimize the number of appointments. The growing availability of digital impression technology and

CAD/CAM denture fabrication (discussed further below) can significantly streamline treatment by reducing clinical visits and eliminating some conventional steps. Overall, an individualized approach is key: one early case report emphasized that every patient with a mental disorder “requires an individual approach from the first contact through diagnosis and treatment planning,” and that mental status alone should never be a reason to refuse dental care [4]. Modern planning acknowledges this, aiming to adapt the treatment to the patient rather than excluding the patient from treatment.

3. Clinical Adaptations and Materials for Removable Prostheses

Delivering dentures to patients with mental disorders often necessitates clinical technique adaptations and the use of advanced materials to improve outcomes. During clinical procedures (impressions, jaw relation records, try-ins, and fittings), the clinician may need to modify standard techniques. For example, when managing patients with conditions like ASD or severe anxiety, the use of the “tell–show–do” desensitization technique is recommended during impressions and fittings, allowing the patient to gradually become familiar with instruments and procedures [3] [7]. In patients who cannot cooperate even with behavioral techniques, obtaining impressions under sedation or GA might be the only viable option. In such cases, the dental team must be prepared to take all necessary records in one session. This might include using fast-setting impression materials or even newer digital intraoral scanners if the patient can tolerate a scanning wand, which can be quicker than traditional methods. Clinicians should also simplify denture designs where possible (avoiding overly complex partial denture designs that might be difficult for the patient to insert or clean).

Advanced prosthetic materials can significantly benefit this population by enhancing comfort, fit, and durability. Traditional acrylic resin dentures are rigid and can cause sore spots – a particular problem if a patient cannot easily communicate pain or discomfort (as in advanced dementia or non-verbal individuals). To address this, soft liners can be applied to the fitting surface of the denture to provide a cushioning effect, reducing pressure on the mucosa. These silicone or rubbery liner materials are especially useful during the adaptation period or for patients with very sensitive oral tissues. Another innovation is the use of flexible thermoplastic dentures. Instead of a hard acrylic base, these dentures (often made from nylon or polyamide materials) are semi-flexible. They tend to adapt more closely to tissue undercut areas and may offer improved comfort and aesthetics (no visible metal clasps), which can be advantageous for patients who might otherwise find a traditional hard denture intolerable [8]. Flexible removable partial dentures have been reported to improve patient satisfaction in some cases, though it should be noted they can sometimes have slightly reduced retention compared to rigid bases and may incur higher cost [8]. For patients prone to dropping or fracturing their prosthesis (which can happen if a patient has tremors, as in certain neurological disorders, or handling difficulties), flexible dentures or high-impact acrylics add resiliency and reduce the risk of breakage. Additionally, incorporating dental implants to assist with denture retention is an advanced option that has shown success in carefully selected patients with mental disabilities. For example, a clinical report described a middle-aged patient with Down syndrome (moderate intellectual disability) who was successfully rehabilitated with a single implant-retained partial overdenture, significantly improving the prosthesis’ stability and the patient’s confidence in using it [5]. Implant-assisted overdentures can provide better chewing efficiency and security (the denture is less likely to dislodge unexpectedly), which may in turn encourage greater use and acceptance of the prosthesis. However, implant surgery and aftercare require careful case selection – the patient (and caregiver) must be able to maintain oral hygiene around implants

and attend follow-ups. In cases of severe mental illness or advanced dementia, conventional dentures or transitional appliances may be more practical than implants, due to the invasiveness and maintenance demands of implant therapy.

Digital technology is another advanced approach to transforming removable prosthodontics. Digital dentures are fabricated using CAD/CAM milling or 3D printing techniques after either an intraoral digital scan or a conventional impression that is later digitized. These methods yield a highly accurate fit and can substantially reduce the number of appointments. Studies have shown that a digital workflow can eliminate certain intermediate visits (like multiple try-ins) and shorten overall treatment time by 40–50%, which is beneficial for patients who have difficulty with frequent dental visits [7]. Moreover, digitally milled dentures often have fewer pressure spots and require fewer post-insertion adjustments, further easing the adaptation process for patients who might otherwise become frustrated by discomfort [7].

In sum, employing state-of-the-art materials and techniques — from flexible denture bases and soft liners to implant supports and digital fabrication — can greatly enhance the comfort, function, and efficiency of denture therapy for patients with mental health conditions.

4. Psychological and Communicative Approaches to Patient Management

Successful prosthetic rehabilitation in this population hinges not only on the physical denture itself, but also on the psychological management of the patient. Mental disorders can affect a patient's ability to understand the treatment, cope with change, and trust the dental team. Thus, building a strong dentist-patient relationship — often termed the “treatment alliance” — is fundamental. Research indicates that when a dentist invests in empathetic communication and emotional support, it moderates the clinical encounter and improves outcomes, especially in denture provision, where trust and reassurance help the patient adapt to the prosthesis [9]. Patients with mental disorders may experience heightened anxiety during dental visits or may be suspicious, uncooperative, or fearful. Dentists should approach these appointments with patience, calmness, and flexibility. Scheduling appointments at a time of day when the patient is usually most stable or cooperative (for example, morning for patients with dementia who may sundown in the afternoon) is a simple but effective strategy. The presence of a caregiver or family member can provide comfort and assist with communication — caregivers can help explain the patient's typical behaviors or triggers and can reinforce instructions given by the dentist.

Using behavioral management techniques is critical, especially for those with developmental disorders (like autism or intellectual disability). Techniques such as Tell–Show–Do (explaining procedures in simple language, demonstrating on a model or on the patient without action, then proceeding with the action), positive reinforcement, and desensitization through repeated gentle exposure can improve cooperation over time [7]. For patients with autism spectrum disorder, maintaining a predictable routine and environment is helpful — the dental team should ensure the operatory is quiet, lights are not too intense, and possibly allow the patient to bring a comforting object or listen to music on headphones if it calms them. These patients can be hypersensitive to sensory stimuli and resistant to changes, so a new prosthesis in their mouth may initially be upsetting. Gradual introduction of the denture (having them wear it for short periods and praise tolerance) can be employed. It's also important to use clear, concrete communication; abstract concepts should be avoided. Instead of saying “This denture will improve your mastication,” one might say “These are new teeth to help you chew food better — let's practice putting them in.”

Many patients with serious mental illness may have cognitive deficits or memory issues (for instance, schizophrenia can involve cognitive impairment, and major depression can affect concentration), so instructions must be repeated and provided in writing or via demonstration to caregivers.

In some cases, pharmacological adjuncts are needed to manage extreme anxiety or challenging behavior during treatment. Short-acting anxiolytic medications (such as benzodiazepines) can be prescribed before appointments if deemed safe, or nitrous oxide sedation can be utilized for mildly anxious but cooperative patients. For those who cannot manage these means, as mentioned, deep sedation or GA might be required even for making the dentures. Although GA carries risks and costs, it can humanely facilitate necessary dental care in individuals who would otherwise go untreated. Importantly, the shift in recent years has been towards using GA as a last resort, only after attempting behavioral approaches; but when it is used, it should be accompanied by a robust prevention plan post-operatively to avoid recurring invasive procedures [3]. Once the dentures are delivered, the psychological support continues – follow-up calls and visits in the first days and weeks are recommended to address any patient concerns, reinforce positive progress, and adjust the prosthesis as needed. Denture acceptance can be emotionally challenging; patients might initially feel a sense of loss or oddity wearing a removable prosthesis. Here, simple counseling and encouragement can make a difference. For instance, showing the patient how their appearance and speech have improved with dentures can boost their confidence.

In refractory cases of denture intolerance linked to psychological factors, referral to or co-management with a psychologist experienced in health anxiety or behavioral therapy might be beneficial. Overall, approaching the patient with understanding and adapting the care to their psychological needs greatly increases the likelihood of success in denture therapy.

5. Enhancing Compliance and Long-Term Maintenance

Compliance with using and caring for dentures is a major concern in this patient group. Mental disorders can impair motivation, memory, and executive function, which may lead to improper use of dentures or neglect of maintenance. To ensure long-term success, strategies must be in place to support and simplify the patient's adherence.

The first step involves caregivers or family members in the treatment process from the beginning. Caregivers should be instructed on daily denture care (cleaning the prosthesis, removing it at night, storing it safely) so they can assist or supervise the patient as needed. Written instructions with pictograms can be very useful, especially for patients with limited literacy or cognitive understanding – for example, a simple poster in the bathroom illustrating step-by-step how to brush the denture and rinse the mouth.

Another key to compliance is making the dentures as user-friendly as possible. This includes ensuring optimal fit and comfort (using the material innovations described earlier) so that the patient does not abandon the prosthesis due to pain or difficulty. If a patient finds the dentures uncomfortable or non-retentive, they are likely to stop wearing them. Regular follow-up appointments should be scheduled to check on adaptation; however, research has shown that getting patients with mental disorders to attend follow-ups can be challenging. In one study of special-needs patients treated under GA, only 17.6% of patients adhered to their scheduled recall visits [3]. To combat this, the dental team may need to proactively reach out with reminders via phone calls or messages and coordinate with caregivers for transportation or encouragement. Setting up shorter interval recalls initially (e.g., one week, one month, three

months) helps catch problems early and, also reinforces the patient's importance of ongoing care.

When patients live in institutional settings (such as group homes or psychiatric facilities), collaborating with the nursing staff is critical. Staff can help with daily denture placement and removal and monitor issues like sore spots or the patient refusing to wear the device. It is also wise to fabricate spare dentures if resources allow, particularly for forgetful or institutionalized patients, since loss or misplacement of dentures is common (for instance, dentures wrapped in tissue can accidentally be thrown away, or a dementia patient might hide or drop them). Labeling dentures with the patient's name (using an indelible marker or microchip insert) is a simple step to aid recovery if lost, especially in nursing homes or hospitals.

Long-term maintenance of oral health remains important even with dentures. Patients and caregivers should continue oral hygiene for any remaining natural teeth and oral tissues. Dentists should emphasize that dentures need periodic adjustments or relines as the mouth changes; this is an often-overlooked aspect of care in populations that already under-utilize dental services. Education about diet is also relevant: a patient who has new dentures might revert to a cariogenic soft diet (high in sugars) if they find chewing challenging. Dietary counseling can encourage a balanced diet that the patient can manage with their prosthesis, thus supporting both oral and general health.

Finally, it is noteworthy that providing proper dentures and ensuring their use is not only about oral function – emerging evidence suggests it may have broader health benefits. Restoring an edentulous patient's ability to chew effectively with dentures can improve nutritional status and has been correlated with slower cognitive decline in the elderly [4]. In patients with dementia, using dentures to re-establish masticatory function might even act as a protective factor for brain function by maintaining sensory input and nutrition [4]. This reinforces the importance of helping patients keep their dentures in daily use. The dental team's role extends to motivating and problem-solving with the patient (and their support network) to overcome any barriers to using the prosthesis consistently. In summary, enhancing compliance requires a supportive, simplified regimen and continued patient engagement, ultimately leading to better prosthetic outcomes and overall well-being.

Conclusion

Advancements in removable denture therapy, from individualized planning and sedation techniques to innovative materials and compassionate behavioral management, have made it increasingly feasible to rehabilitate patients with a wide range of mental disorders. Rather than excluding these patients from prosthetic care, clinicians now strive to adapt treatments to meet their special needs. The contemporary approach combines clinical innovation with empathy: high-precision digital dentures and flexible materials, all of which go hand in hand with patience, trust-building, and caregiver involvement. When executed with these advanced approaches, denture therapy can markedly improve not only oral function and aesthetics for patients with mental disorders, but also their nutritional status, social interactions, and overall quality of life. Ongoing research continues to underscore that oral health is an integral component of mental and cognitive health; thus, providing appropriate removable prostheses to this vulnerable population is a critical aspect of holistic, advanced healthcare. With a commitment to collaboration and creativity in care, dental professionals can achieve successful prosthodontic outcomes that empower patients with mental disorders to enjoy the benefits of a healthier smile.

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PART IV. GEOGRAPHY SECTION



Figure P4. Geography Section — Spatial Analysis and Environmental Exploration

This illustrative plate was created collaboratively by S.M. Bălan and an AI-assisted design system to convey the study of physical and human landscapes, spatial relationships, and geographic methodologies.

THE QUALITY OF WATER RESOURCES IN RURAL AREAS AND THE IMPACT ON THE POPULATION'S HEALTH IN MURES COUNTY, CENTRAL REGION

Associate Professor Ramona Flavia RAȚIU Ph.D., Rector¹; Lecturer Marius CIGHER¹, Lecturer Claudia NISTOR Ph.D.²

¹"Dimitrie Cantemir" University of Târgu Mureș, Faculty of Geography, Romania;

²Faculty of Medicine, Romania

Corresponding author: Ramona Flavia Rațiu: ratiuflavia@yahoo.com

Abstract

Water quality is a crucial determinant of public health, particularly in rural areas where natural resources and anthropogenic factors coexist in a delicate balance. This study analyses the quality of water resources in Mures County, Central Region of Romania, highlighting the correlations between physical, chemical, and biological indicators and their impact on the population's health balance. The research is based on data collected from local monitoring systems, complemented by field observations and secondary sources from regional public health authorities. Results indicate that nitrate contamination, improper waste management, and limited access to modern water treatment systems remain the main risk factors affecting drinking water safety. The paper emphasises the need for integrated policies that combine environmental protection, sustainable water management, and community education to improve both environmental and public health outcomes.

Keywords: water quality; rural environment; public health; sustainable development; Romania; pollution indicators; groundwater; environmental management

Introduction

The quality of the water we consume every day has a profound impact on the health and quality of life of the population. In Romania, challenges related to water quality are exacerbated by the fact that a significant percentage of the population relies on individual water sources, such as wells, boreholes or springs, a situation that highlights the vital importance of complying with quality standards and applying an appropriate legislative framework to ensure access to safe drinking water [1].

The Overall Situation in Romania

The regulatory framework for drinking water quality in Romania is governed by a series of national legislative acts, harmonised with the European Union directives. Law No. 458/2002 on drinking water quality, amended by Law No. 311/2004, sets limit values for microbiological and chemical parameters and stipulates the obligations of water authorities and operators regarding water quality monitoring and reporting [2, 3]. The protection of water resources and integrated river basin management are regulated by Water Law No. 107/1996 [4].

The methodological rules for monitoring and controlling drinking water quality are further detailed in Government Decision No. 974/2004, while the classification of surface water quality used as drinking water sources is regulated by Order No. 161/2006, which establishes ecological and chemical quality standards for surface waters [5], [6].

In Romania, the challenge of ensuring access to safe drinking water is intensified by the fact that approximately 30% of the population relies on individual water sources, such as wells or boreholes. This situation, which is largely unique within the European Union, raises serious concerns regarding the safety, monitoring, and compliance of drinking water quality, particularly in rural and peri-urban areas where centralized water supply systems are absent [1].

The Importance of Assessing Water Quality in the Rural Areas of Mureș County

In the rural areas of Mureș County, water from wells and springs is an essential resource for human consumption, household activities and animal farming. In many localities, the lack of centralised water supply networks or their insufficient coverage means that a significant proportion of the population depends on traditional water sources. Although these resources are often perceived as 'natural' and therefore safe, they can be vulnerable to contamination due to their proximity to agricultural activities, households and improvised sanitation facilities.

Regular assessment of the quality of water from wells and springs is therefore essential for protecting public health. The microbiological and chemical parameters of water can vary depending on environmental factors, soil type, rainfall patterns and how household and agricultural waste is managed. Without monitoring, risks may remain hidden and the population may use water that is potentially harmful to health without being aware of the associated dangers.

The importance of water quality assessment is not limited to preventing waterborne diseases, but also to identifying trends in the degradation of local resources, supporting authorities in developing protection policies, and providing a solid basis for effective interventions in vulnerable communities. In Mureș County, where agricultural activities and scattered housing are characteristic to the rural environment, proper management of water sources becomes a key element in ensuring a high standard of living and protecting future generations.

Material and Method

Descriptive statistical methods and, where spatial information allowed, geographic analysis procedures (GIS) were used to interpret water quality data in rural areas of Mureș County. These tools helped to identify contamination patterns, highlight high-risk areas and correlate the analysed parameters with environmental and socio-economic factors.

Data Sources

The analysis of water quality in wells and springs located in rural areas of Mureș County was based on data provided by official institutions relevant to the monitoring and assessment of environmental factors and public health.

The main sources of information used were:

- The Environmental Report of Mureș County, which provides data on the state of water resources, chemical and microbiological parameters monitored annually, as well as developments identified in different areas of the county.

- The Mureş Public Health Directorate (DSP Mureş), through its reports on the quality control of drinking water in rural areas in 2023 and 2024.

These documents include the results of analyses of samples taken from public wells, individual wells and springs used by the population for daily consumption.

Combining these two sets of data provided us with an integrated picture of water quality in rural areas, both in terms of environmental impact and health risks.

Data Collection and Methods of Analysis

Data from periodic monitoring carried out by the competent authorities was used to prepare the analysis. The methodology involves taking the results of the samples analysed in accredited laboratories and published in official reports and comparing the parameters obtained with the permissible values set out in national legislation on drinking water.

The data was interpreted in accordance with European and national standards on drinking water quality, Law No. 458/2002 [3], as amended, harmonised with EU Directives on water for human consumption.

QGIS 3.40.5 software and vector data on the boundaries of Mureş County and the boundaries of the administrative-territorial units (ATUs) were used to create the cartograms. This data is in shapefile format and was downloaded from the geo-spatial.org website. Pie charts were inserted using the Layer diagram options command, according to the data entered in the attribute table associated with the UATs. The statistical data was downloaded from the www.aspms.ro website.

Indicators Analysed

Water quality was assessed through the integrated analysis of microbiological and physico-chemical indicators considered relevant for identifying faecal contamination and chemical pollution. Microbiological indicators, namely coliform bacteria, *Escherichia coli* and enterococci, are used to highlight recent or persistent faecal contamination and to estimate the associated microbiological risk. Physicochemical indicators, including turbidity, hardness, oxidizability, ammonia, nitrates and nitrites, allow the characterisation of organic loading, the assessment of the influence of anthropogenic activities and the evaluation of the toxicological potential of water. The analysis of these parameters provides the basis for determining compliance with current quality standards, identifying high-risk areas and formulating the necessary recommendations to protect public health.

Analysis of Microbiological and Physico-chemical Parameters of Water

At the European level, the principles of sustainable water resource management are established by the Water Framework Directive 2000/60/EC, which introduced the concept of achieving “good status” for all water bodies and promoted an integrated management approach at the river basin level [7]. Furthermore, quality standards for water intended for human consumption are defined by Directive 98/83/EC, subsequently updated and replaced by Directive (EU) 2020/2184, which strengthens risk-based assessment across the entire water supply chain, enhances transparency requirements, and extends monitoring obligations to emerging contaminants [8]. The standards used in the analysis of water quality indicators are those set out in Law 458/2002 on drinking water quality.

Bacteriological contamination (coliforms, *E. coli*, enterococci) represents recent or chronic faecal contamination with an increased risk of infectious disease, requiring intervention

measures related to the use of water from such sources. The major risk is to children, the elderly and immunocompromised individuals.

The analysis of the coliform bacteria parameter shows that most of the sources investigated have positive values, sometimes extremely high, with concentrations reaching up to 140–150 CFU Colony Forming Units/dL. Only a small number of sources register a value of zero, which indicates microbiologically safe water for consumption. The presence of coliforms is a clear indicator of contamination with organic matter or surface water, suggesting either indirect infiltration of faecal origin or a lack of adequate sanitary protection of sources.

Enterococci

Enterococci have been identified in numerous sources, with high values such as 80, 76 or 63 CFU/dL, and in some cases the concentrations are exceptionally high. These indicators are associated with old and persistent faecal contamination, suggesting structural problems with the source and continuous infiltration. The presence of enterococci justifies immediate measures to close the source and remediate the sanitary protection zone, as the water poses an unacceptable microbiological risk [9].

Physicochemical Contamination Turbidity

For the turbidity parameter, all records analysed indicate a value of zero. This may reflect either the absence of suspended particles or the fact that the parameter was not measured or reported appropriately. In the absence of variable data, no conclusive interpretation can be made regarding water clarity or sedimentation processes.

Hardness

All reported values for hardness are zero, which raises the suspicion that the parameter was not determined or was not entered in the table. In the absence of actual values, it is not possible to assess the mineral composition of the water and its impact on consumption or installations.

Oxidizability (KMnO₄)

Most sources show very low or zero values for oxidability, but a few show high values, such as 121 or 152 mg O₂/L. Increased oxidability indicates the presence of large amounts of organic matter, active biological processes, or contamination with substances from vegetation decomposition or surface water pollution. Associated risks include secondary chemical reactions in drinking water and an increased potential for bacterial growth, which can exacerbate microbiological problems.

Ammonia (NH₄⁺)

Ammonia is absent in most sources, but a few show significantly increased values, reaching 6,643, 5,060 or 3,901 mg/L. High ammonia concentrations indicate recent pollution, most commonly through the infiltration of animal manure, domestic wastewater or anaerobic processes in the water table. Ammonia is an important indicator of raw water quality degradation and can contribute to the formation of nitrites and nitrates. The risks are particularly high for infants, for whom exposure can have toxic effects.

Nitrates (NO_3^-)

Nitrate values are predominantly high, with many sources significantly exceeding the limit of 50 mg/L, with values such as 147, 141 or 128 mg/L. This situation reflects the contamination of the aquifer with agricultural fertilisers, animal manure or infiltrations from landfills or leaky latrines. Nitrates pose a major risk to the health of infants, being directly involved in the onset of methemoglobinemia ("blue baby syndrome"), but they can also affect thyroid function and metabolism in adults.

Nitrites (NO_2^-)

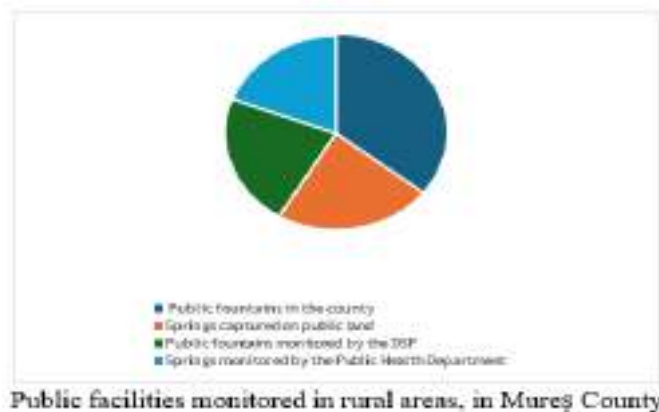
In all reported sources, nitrites show a value of zero. This result may indicate either the actual absence of nitrites — which are unstable compounds that rapidly oxidise to nitrates — or the lack of effective analysis of the parameter. The relationship between high nitrate values and zero nitrite values suggests either the complete oxidation of existing nitrites or incomplete reporting. In the absence of an explicit correlation, interpretation requires caution.

Water Quality Analysis by Municipality in Mureş County (2024)

3. General Situation of Drinking Water Sources in Rural Areas of Mureş County

In Mureş County, a significant portion of the rural population still depends on traditional water sources: public wells, individual wells, and captured springs. DSP monitoring shows that these sources are significantly vulnerable in terms of water quality standards.

Graphic 1. Level of non-compliance (rural)



The assessment of water quality in the municipalities of Mureş County shows that 58 public wells have been declared unsuitable and banned from use, and 16 springs have been declared unsuitable and banned (DSP 2024 report). The figure indicates a high proportion of non-compliant sources, which represents a significant risk to the health of consumers in rural areas. There are major differences between areas, but the dominant trend is one of high or severe risk, particularly in terms of microbiological contamination and elevated nitrate levels. Based on the indicators analysed, municipalities were classified into four risk categories: major, high, moderate and low.

Communes with Major Risk – Widespread Contamination and Undrinkable Water

A significant number of municipalities face widespread contamination of water sources, both bacteriological and chemical. In these localities, the values for coliform bacteria, *E. coli* and enterococci are very high, and nitrates frequently exceed the permitted limits. Communes such as Vânători, Sânpetru de Câmpie, Ibănești, Fântânele, Ernei, Sângeorgiu de Mureș, Gornești, Măgherani, Pănet and Band present a severe picture, with water from all analysed points being undrinkable. Extreme values – such as 150 coliform bacteria in Fântânele or nitrates above 110 mg/L in Ernei – suggest persistent faecal contamination and a pronounced level of organic pollution.

Similar situations are also reported in municipalities such as Mădăraș, Beica de Jos, Petelea, Ceuașu de Câmpie, Chețani, Solovăstru, Iclânzul, Păsăreni, Breaza, Adămuș, Daneș, Saschiz, Nadeș, Apold, Glodeni and Lunca, where between 90% and 100% of sources are contaminated. In these areas, the water is constantly undrinkable, and the health risks are significant, especially for children and the elderly. Overall, these municipalities require urgent intervention, including the rehabilitation of wells, improved drainage, protection of sources and the implementation of a regular disinfection programme.

High-risk Municipalities – Most Sources Are Non-compliant

A second category includes municipalities where, although there are some moderate or isolated acceptable values, most of the sources analysed remain non-compliant. Relevant examples are Acățari, Bălăușeri, Ideciu de Jos, Voivodeni and, partially, Breaza.

In Acățari, for example, the presence of ammonia in some sources and high nitrate concentrations in others indicate active organic pollution, while bacteriological values remain unstable. In Bălăușeri, there is only one drinking fountain, but the rest show significant chemical non-compliance. In Ideciu de Jos and Voivodeni, bacterial contamination is almost universal, and nitrates frequently reach values between 60 and 128 mg/L, suggesting persistent infiltration from agricultural or household activities. Even in Breaza, where there are two drinking water sources, the rest of the points are compromised by faecal contamination or high oxidability.

These municipalities are therefore at the upper end of the risk scale, requiring control and remediation measures in the short and medium term. Communes with moderate risk – isolated contamination and partially acceptable sources

Communes classified as moderate risk present a less alarming picture, although problems are not absent. In Rușii Munți, for example, bacterial contamination has only been reported in isolated cases, without extreme values, suggesting localised and potentially remediable problems. In Sâncraiu de Mureș, one spring is drinkable, but the rest have high nitrate concentrations, which limits the use of water by infants. In Lunca Bradului, the Neagra spring stands out as a safe source, while the other point analysed shows slight contamination. A similar situation can be found in Răstolița, where only one of the sources meets the criteria for potability.

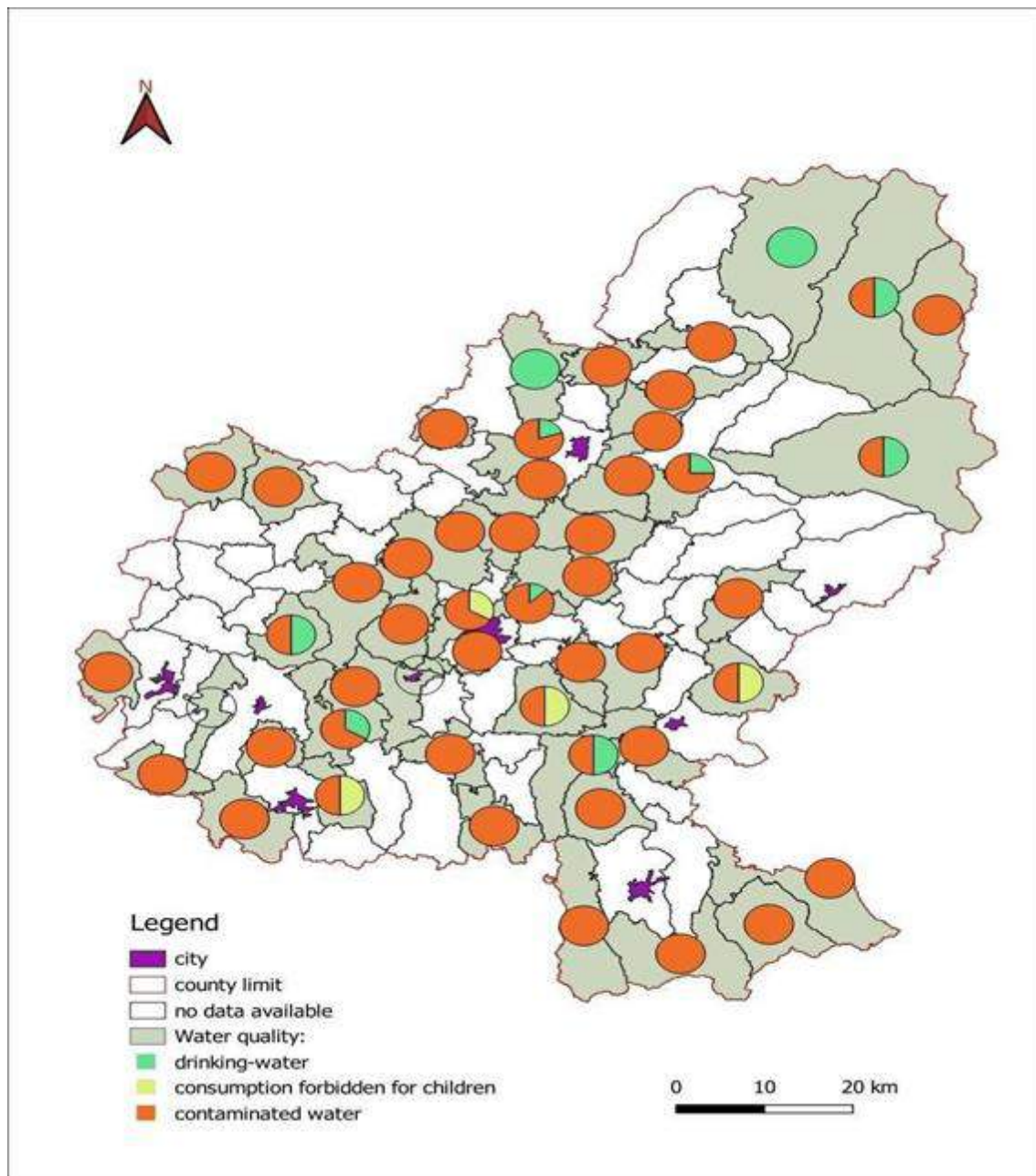
These municipalities can achieve an acceptable level of safety if specific remedial measures are implemented.

Low-risk Municipalities – Existence of Safe Drinking Water Sources

The low-risk category includes only a few localities where at least one analysed source is drinkable without restrictions. These include Ibănești (Călin spring), Beica de Jos (Șerbeni), Lunca Bradului (Neagra), Batoș (Monor spring), Ungheni (Recea spring) and Ogra (Vaideiu).

These sources are rare examples in the county that fully comply with microbiological and chemical parameters, serving as benchmarks for good practices in spring protection and maintenance.

However, even in these municipalities, drinking water sources coexist with non-compliant ones, which highlights the fragmented nature of water quality in rural areas and the need for continuous monitoring.



Overall situation of drinking water sources in rural areas of Mureș County (2024)

Table 1. Water quality indicators exceeding the maximum permissible concentration in rural water supply sources in Mureş County in 2023 and 2024 and their impact on health

Parameter	Source/Cause	Health effects	Associated diseases / Risks
Escherichia coli (E. coli)	Faecal contamination, seepage, animal waste	Acute digestive infections	Gastroenteritis, haemorrhagic colitis, haemolytic uraemic syndrome, septicaemia
Enterococci	Persistent faecal pollution	Digestive and systemic infections	Gastroenteritis, urinary tract infections, wound infections, endocarditis
Ammonia	Agricultural activities, manure, organic degradation	Irritation, digestive disorders	Conversion to nitrites – indirect toxic risk
Nitrates (NO₃⁻)	Agricultural fertilisation, surface water, wells	Severe toxicity in infants	Methemoglobinemia, risk of gastric cancer
Nitrites (NO₂⁻)	Conversion of nitrates, organic pollution	Impairment of oxygen transport	Severe methemoglobinemia, neurological disorders

The presence of *Escherichia coli* and faecal enterococci is a clear indicator of recent faecal contamination of water, suggesting the infiltration of domestic sewage, animal manure or the improper functioning of septic tanks. According to the World Health Organisation, drinking water should not contain any *E. coli*, as this microorganism is associated with an increased risk of infectious diseases [10]. Contamination with coliform bacteria appears to be the most common non-compliance, highlighting the increased vulnerability of rural water sources. The risks associated with such contamination are significant: consumption of such water can lead to acute diarrhoeal diseases and can facilitate the transmission of additional pathogens, with a particular impact on children, the elderly and people with compromised immunity.

Exposure of the population to microbiologically contaminated water is associated with acute gastroenteritis, haemorrhagic colitis, haemolytic-uraemic syndrome and, in severe cases, septicaemia, especially among children, the elderly and immunocompromised individuals [12]. Faecal enterococci, due to their increased resistance in the aquatic environment, indicate persistent contamination and are correlated with gastrointestinal and urinary infections and, more rarely, with bacterial endocarditis [9].

The presence of ammonia in water indicates organic pollution, being associated with intensive agricultural activities, the degradation of organic matter or faecal contamination. Although ammonia is not considered highly toxic at low concentrations, it can cause mucosal irritation and digestive disorders and promotes the biological conversion of nitrates to nitrites, thereby increasing the risk of indirect toxicity [12].

Nitrates and nitrites pose a major health risk, especially for infants. Consumption of water with high nitrate content is associated with infantile methemoglobinemia, known as 'blue baby syndrome', a potentially fatal condition characterised by reduced oxygen-carrying capacity in the blood [10]. Nitrites, which are much more toxic than nitrates, can induce severe tissue hypoxia, neurological disorders and acute digestive symptoms.

In the long term, chronic exposure to nitrates and nitrites is discussed in the literature as a risk factor for gastric cancer, through the formation of nitrosamines in the body, as well as for impaired thyroid function [13].

Conclusions

The results of the assessment of drinking water quality in rural areas of Mureş County, based on the analysis of microbiological and physico-chemical parameters, in relation to the requirements imposed by Law No. 458/2002, highlight the existence of major deficiencies in terms of the safety of water sources used by the rural population, confirming their vulnerability to contamination and significant risks to public health.

Microbiological analysis has shown that most of the sources investigated are contaminated with coliform bacteria, enterococci and, implicitly, faecal germs, indicating either recent contamination or persistent chronic pollution. According to legal standards, the presence of these microorganisms makes the water unfit for human consumption, and its use for drinking purposes poses a major risk, especially for vulnerable population groups such as children, the elderly and immunocompromised individuals. Microbiological contamination thus remains the main factor limiting the potability of water in the rural environment analysed.

From a physical-chemical point of view, the study highlighted significant exceedances of the permissible values for nitrates and ammonia, indicating pollution of the aquifer associated with agricultural, livestock and household activities, as well as the lack of adequate sewage infrastructure. High levels of nitrates [14] pose a particular danger to the health of infants, as they are linked to the onset of methemoglobinemia, but they can also have long-term adverse effects on the adult population. Increased oxidability values confirm the presence of excess organic matter, favouring biological processes and increasing the microbiological risk.

Although certain parameters (turbidity, hardness, nitrites) were reported with zero values, this uniformity suggests limitations in the process of determining or reporting data, highlighting the need to strengthen the monitoring system and to conduct a comprehensive and accurate assessment of water quality.

The territorial analysis showed that most of the municipalities in Mureş County fall into the major and high-risk categories, with a significant number of public wells and springs declared unsuitable and subject to a ban on use. There are differences between localities, but the general trend is one of constant water unfitness for consumption, caused by multiple and persistent contamination.

In conclusion, the results of this study confirm that access to safe drinking water in rural areas of Mureş County is a major public health issue. The situation requires the adoption of urgent and integrated measures, including the sanitary protection of sources, the rehabilitation of wells and springs, the implementation of efficient water treatment and disinfection systems, the control of agricultural and domestic pollution sources, as well as the information and education of the population. The consistent application of these measures is essential to reduce health risks and bring drinking water quality into line with national and European standards [5]-[19].

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STUDY METHODS OF RURAL SETTLEMENTS AND INNOVATIVE APPLICATIONS IN GEOGRAPHY DIDACTICS TO ADAPT TO CONTINUOUS CHANGES IN THE ARTIFICIAL INTELLIGENCE ERA

Associate Professor Ramona Flavia RAȚIU Ph.D.; Lecturer Adrian TORPAN Ph.D.

*“Dimitrie Cantemir” University of Târgu Mureș, Faculty of Geography, Romania
Corresponding author: Ramona Flavia Rațiu: ratiuflavia@yahoo.com*

Abstract

The contemporary rural space is undergoing accelerated transformation under the influence of digitalization and emerging technologies, particularly artificial intelligence (AI). Traditionally perceived as a stable and predominantly agricultural environment, rural areas are increasingly becoming dynamic, interconnected, and integrated into global information networks. These changes profoundly affect the organization, functioning, and representation of rural settlements, while also generating new educational challenges related to digital competencies and territorial understanding. This paper explores the transition from classical to modern teaching methods in geographic education, with a specific focus on the study of rural settlements in the AI era. It highlights the limitations of traditional, descriptive approaches and emphasizes the pedagogical potential of modern, student-centered methods supported by Geographic Information Systems (GIS), particularly QGIS. Through project-based learning, case studies, spatial investigation, simulation, and multicriteria analysis, students are actively involved in analyzing accessibility, connectivity, and spatial disparities within rural areas. The applied component demonstrates how GIS and remote sensing tools enable quantitative, spatial, and dynamic analysis of rural environments, facilitating both scientific understanding and didactic innovation. The study argues for a hybrid methodological framework that integrates classical conceptual foundations with modern digital tools, fostering geographic, digital, and critical competencies essential for understanding and managing contemporary rural transformations in the context of artificial intelligence.

Keywords: rural settlements; geography didactics; artificial intelligence; GIS education; QGIS; digital competencies; spatial analysis; modern teaching methods

Introduction

Rural areas are undergoing rapid transformation under the influence of digitalization and new emerging technologies, particularly artificial intelligence (AI). Traditionally perceived as a relatively stable territory, characterized by agricultural activities, slow development and conservative socio-economic structures, the contemporary rural environment is becoming increasingly dynamic and connected to global information networks. The digitization of infrastructure expanded internet access, the use of smart technologies in agriculture,

administration, and services, as well as the integration of AI-based tools are contributing to a redefinition of the relationship between rural and urban areas.

Artificial intelligence profoundly influences the way rural settlements are organized, function and are represented, offering innovative solutions for optimizing agricultural production, managing natural resources, spatial planning and improving quality of life. At the same time, these changes generate new challenges related to digital skills, technological gaps, and the adaptation of local communities to a constantly evolving socio-technological context. In this context, the study of rural settlements can no longer be carried out exclusively through traditional methods but require interdisciplinary approaches and advanced digital tools.

Therefore, geography teaching must adapt to these changes by integrating innovative teaching and learning methods that harness the potential of artificial intelligence. The analysis of rural space in the AI era becomes not only a scientific endeavor, but also an educational one, essential for the development of critical thinking, digital skills, and the ability of pupils and students to understand and interpret contemporary territorial changes.

1. Geographical Methodology: The Transition from Classical Teaching Methods to Modern Methods in Geography Teaching

Teaching methodology is the theory and practice of methods used in the learning process [1]. The teaching methodology of geography has undergone significant changes in the context of the evolution of educational paradigms and technological progress. In teaching geography, especially in the study of rural settlements, there has been a gradual transition from classical teaching methods to modern methods focused on skills, interdisciplinarity, and the use of digital technologies.

1.1 Classical Teaching Methods in Geographical Methodology

Classical teaching methods have long been the foundation of geography teaching, playing an essential role in structuring basic knowledge. They are characterized by using wall maps, atlases, and textbooks as the main teaching resources, with an emphasis on the description of geographical space and typological classifications, and predominantly summative assessment focused on the reproduction of information.

In geography teaching, especially in classical teaching methods, frontal teaching and systematic presentation of geographical content are classical teaching methods, teacher-centered, playing an important role in transmitting and structuring basic knowledge, with the advantage of a systematic approach to a topic and a large volume of information [2] but with a limited impact on the development of applied and critical skills.

In traditional geography teaching, cartographic means (maps, diagrams, block diagrams, profiles), graphics (drawings, paintings, games), and written means (textbooks, atlases, dictionaries) are the main teaching resources, being used to locate, describe, and systematize geographical information, in a predominantly frontal teaching setting [3].

Within the framework of classical teaching methods, the teaching of geography is based significantly on the description of geographical space and the creation of typological classifications as fundamental ways of organizing and transmitting knowledge.

Traditional teaching methods emphasize the description of geographical space and the creation of typological classifications as ways of systematizing and transmitting knowledge, favoring a static and descriptive approach to geographical reality.

In the classical teaching methodology, assessment is predominantly summative, usually carried out at the end of a learning unit or chapter. Its main purpose is to verify the level of assimilation of the geographical information conveyed during teaching activities. Although summative assessment contributes to certifying the level of knowledge, its predominant use limits the assessment of complex geographical skills, such as spatial analysis, data interpretation, and the formulation of reasoned explanations.

In traditional geography methodology, the student is placed in a receptive role, and the learning process is mainly oriented towards the accumulation of declarative knowledge.

1.2 Modern Teaching Methods in Geographical Methodology

Modern methods respond to the need to adapt geography to the dynamics of contemporary society and to new educational requirements. They are characterized by active and participatory, student-cantered learning; use of digital tools (educational GIS, interactive maps, simulations); integration of case study, project learning and problematization; formative, continuous and competence-oriented assessment.

1.2.1 Project Learning

Is one of the fundamental modern teaching methods in contemporary geography. Within the analyzed material, this method is illustrated by carrying out a project analysis of spatial relations between rural settlements, the transport network and public services, using QGIS. This method develops autonomy in learning, analytical ability and working skills with real spatial data.

1.2.2 The Case Study Method

Is applied through the analysis of concrete rural territory, using real data and quantifiable indicators. The attached material provides a clear example by analyzing the distance between villages and public services; delimiting areas of influence by buffer methods; assessing accessibility by isochron maps. This method allows the correlation of geographic theory with territorial reality and stimulates the understanding of spatial differences between rural settlements.

1.2.3 Learning Through Investigation and Problematization

Modern methods promote the investigation and formulation of geographical assumptions. In the QGIS-based teaching approach, students are involved in analyzing the relationship between distance, travel time and accessibility; calculating the accessibility indicators (Hansen) and connectivity; identifying areas with poor access to services.

The problem arises when students are invited to explain why certain rural settlements are poorly connected and what socio-economic implications may result.

1.2.4 Spatial Simulation and Modeling Method

Simulation is an essential modern method in geographical methodology. The analyzed material highlights the use of network analysis; transport graph modelling; accessibility simulation through isochrone maps and synthetic indicators. This makes it possible to anticipate

the effects of infrastructure changes or the redistribution of public services, developing forward thinking and decision-making skills.

1.2.5 Multi-Criteria Analysis and Critical Evaluation Method

A modern advanced method is multi-criteria analysis, applied in the material through standardization of indicators; calculation of composite indicators; weighted interpretation of results.

This method contributes to the development of critical thinking, as students are required to justify methodological choices and evaluate the limitations of the models used. Modern teaching methods integrated into geographical methodology, exemplified using QGIS, transform the teaching of geography into an active, investigative, and applied process. These methods go beyond the traditional descriptive approach and contribute to the development of geographical, digital, and civic skills, which are essential for understanding and managing the contemporary rural space.

Modern methodology emphasizes the analysis, interpretation, and explanation of geographical processes, not just their description.

1.2.6 Modern Didactic Methods in Geographical Methodology (with exemplification from the spatial analysis carried out in QGIS)

The modern teaching methods used in the geographical methodology are characterized by student-centeredness, applied approach and use of digital tools, with the main objective of training geographic, digital and analytical skills. In the study of rural settlements, these methods are effectively supported using GIS applications, such as QGIS, which enable the investigation of spatial relations in an interactive and exploratory way.

1.3 Comparative Analysis of Teaching Methods within Geographical Methodology

A comparison of the two types of methods highlights significant differences in terms of: the role of educational actors: teacher-transmitter versus teacher-facilitator; the nature of learning: reproductive versus constructive; the relationship to geographical reality: static versus dynamic; the educational goal: accumulation of information versus development of geographical and civic skills.

This comparative analysis highlights the need for a hybrid methodology that capitalizes on the advantages of both categories of methods.

Table 1. Comparative analysis of teaching methods within geographical methodology

Analysis criterion	Classical teaching methods	Modern teaching methods
Instructional Orientation	Teacher-Centered	Student-Centered
Main methods	Exposition, explanation, description, guided conversation, demonstration	Project-based learning, case study, problem-solving, simulation
Organizational form	Predominantly frontal	Individual, group, collaborative
Student Role	Receiver of Information	Active Participant, Investigator
Learning type	Reproductive	Constructive, exploratory

Analysis criterion	Classical teaching methods	Modern teaching methods
Teaching resources	Manual, atlas, wall map	Educational GIS, digital maps, interactive platforms
Reporting to reality	Descriptive, indirect	Applicative, contextualized
Assessment	Summative, final	Formative, continuous
Skills developed	Basic geographical knowledge	Geographic, digital and critical skills
Adaptability to the AI era	Low	High

Continuing Table 1. Comparative analysis of teaching methods within geographical methodology

A comparison of the two categories of teaching methods highlights significant differences in the educational paradigm. Thus, in the case of traditional methods, the role of the teacher is predominantly that of a transmitter of knowledge, while modern methods position the teacher as a facilitator and mediator of learning.

From the perspective of the learning process, traditional methods favor reproductive learning, oriented towards memorization and reproduction, while modern methods support constructive learning, based on exploration, analysis, and reflection.

The relationship to geographical reality also differs significantly: classical methods treat geographical space in a static and descriptive manner, while modern methods approach geographical reality from a dynamic, contextualized and evolutionary perspective.

In terms of educational goals, classical methods focus primarily on the accumulation of information, while modern methods aim to develop the geographical and civic skills needed to understand and manage contemporary spatial processes.

The transition from classical to modern teaching methods is a necessary process in current geographical methodology. A balanced methodological approach contributes to the efficiency of teaching geography and the development of the skills necessary to understand and manage territorial changes in the era of artificial intelligence.

2. The Applied Component of the Study of Rural Areas Using Modern Methods

The applied component of the research aims to capitalize on modern methods of geographical analysis in the study of rural areas, using geographic information systems (GIS), with a focus on the QGIS application [4]. This approach allows us to go beyond the descriptive nature of traditional analysis and facilitates quantitative, spatial, and dynamic investigation of rural reality, with both scientific and educational relevance.

The applied methodology is structured in stages and includes the analysis of spatial relationships between rural settlements, transport infrastructure, and public services. Spatial data are organized and validated topologically, using vector, raster, and network analyses to assess distance, accessibility, and territorial connectivity [5]. These approaches allow spatial differences to be highlighted and rural areas with poor access to essential services to be identified.

The first level of the applied component is the creation of maps showing the location of rural settlements in relation to the national territory (*Fig.1*). This stage serves to contextualize the study territorially and to develop spatial orientation and representation skills through the correct use of coordinate systems, cartographic symbols, and map composition elements. The maps obtained are essential visual aids for further geographical analysis.

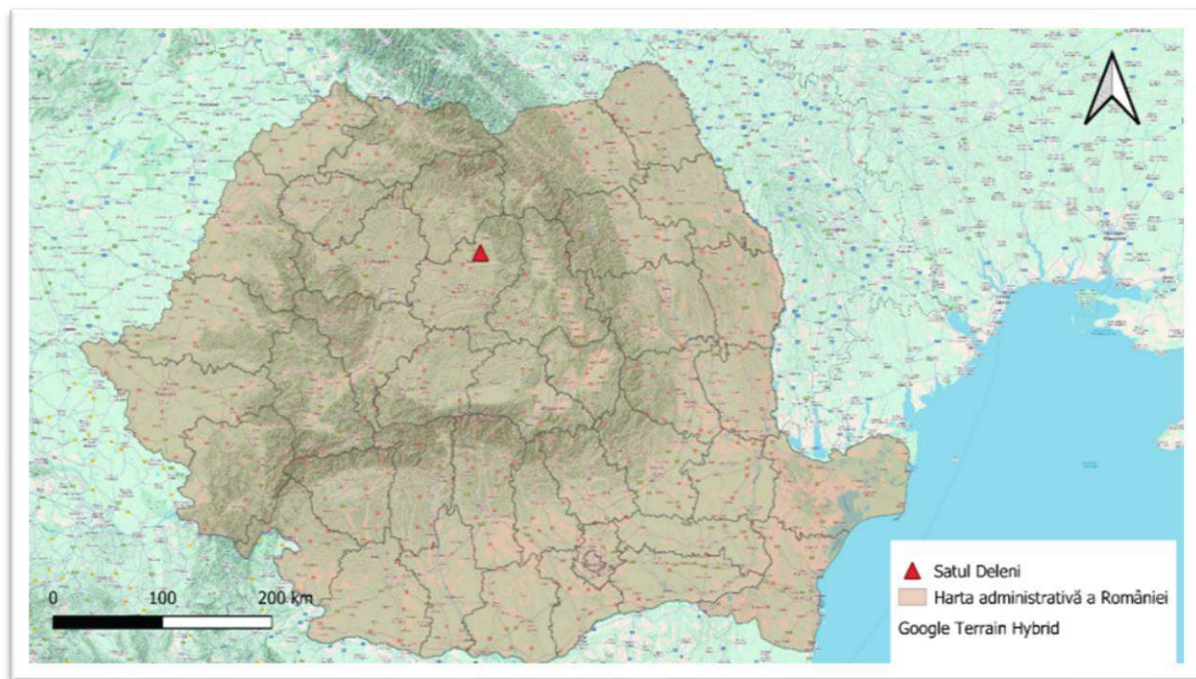


Fig. 1. QGIS, tools for creating maps showing the location of a rural locality in relation to the country's surface area

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Creating analytical maps in QGIS using remote sensing to monitor rural dynamics requires the application of a rigorous methodology that combines satellite data with GIS tools for the spatiotemporal analysis of changes in the rural environment [6]. (Fig.2).

From an educational perspective, the integration of QGIS and remote sensing supports modern teaching and learning methods, such as project-based learning, case studies, and inquiry-based learning. Pupils or students are actively involved in the collection, analysis, and interpretation of spatial data, which contributes to the development of geographical, digital, and analytical skills. At the same time, this approach stimulates critical thinking and the ability to correlate geographic data with the socio-economic reality of rural areas.

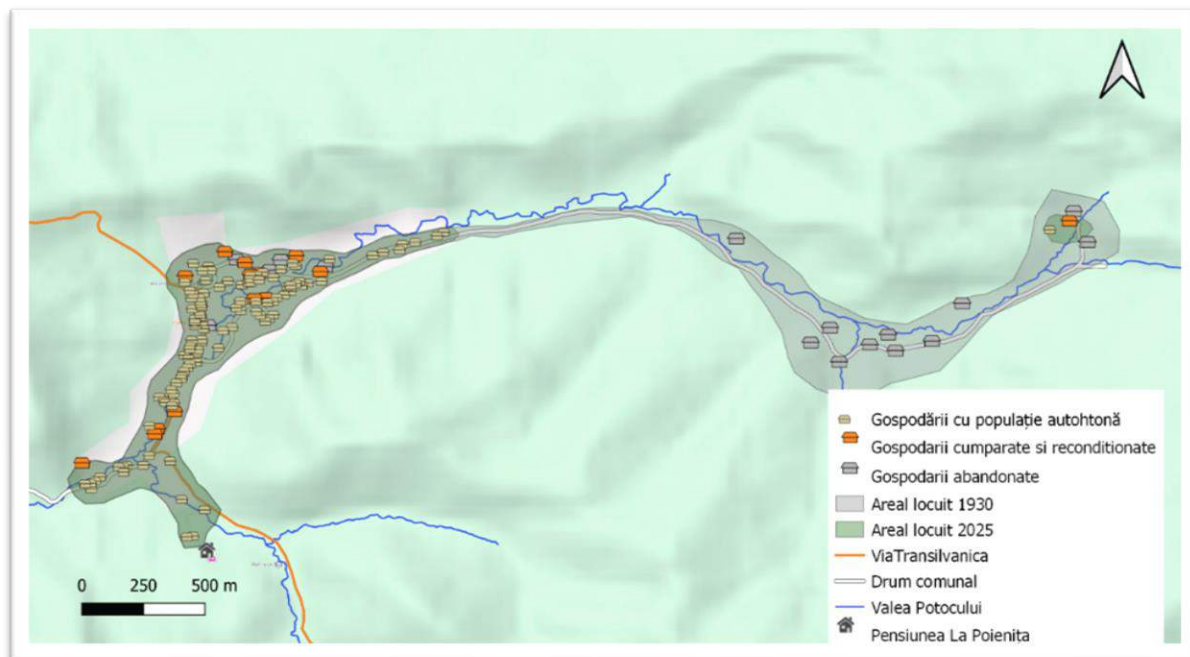


Fig.2. Rural dynamics analytical maps

The methodology for creating analytical maps in QGIS using remote sensing to monitor rural dynamics involves a series of well-defined steps, from data selection and pre-processing to analysis and cartographic representation [7]. This approach provides an effective tool for understanding and managing changes in rural areas.

The application component based on modern GIS and remote sensing methods demonstrates their effectiveness in the study of rural areas and their educational relevance in the current educational context. The integration of these tools contributes to the modernization of rural geography and the adaptation of the teaching process to the requirements of the digital age and artificial intelligence.

Conclusions

The study confirms that the transformation of rural spaces in the era of artificial intelligence requires a corresponding transformation in the methodology of geographic education. Classical teaching methods remain valuable for establishing fundamental geographic concepts and terminology; however, when used exclusively, they limit students' ability to understand the dynamic, complex, and interconnected nature of contemporary rural systems.

Modern didactic methods supported by GIS and remote sensing tools significantly enhance the study of rural settlements by promoting active learning, spatial investigation, and critical thinking. The use of QGIS enables students to analyze real spatial data, assess accessibility and connectivity, simulate territorial scenarios, and interpret rural dynamics in a quantitative and contextualized manner. These approaches not only improve geographic understanding but also contribute to the development of digital and analytical competencies essential in the AI era.

A balanced, hybrid methodological framework that integrates classical and modern approaches emerges as the most effective solution for geographical education. Such integration supports the modernization of rural geography teaching and ensures that learners are better

prepared to interpret, manage, and respond to ongoing territorial transformations driven by digitalization and artificial intelligence.

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REGENERATIVE TOURISM AND LOCAL IDENTITY IN TRANSYLVANIAN COMMUNITIES: FROM CONSERVATION TO CO-CREATION

Associate Professor Maria OROIAN Ph.D., Vice-rector

"Dimitrie Cantemir" University of Târgu Mureș, Faculty of Geography, Romania
Corresponding: Oroian Maria: oroianmaria@yahoo.com

Abstract

This study will explore how regenerative tourism can serve as a catalyst for cultural and ecological renewal within Transylvanian rural communities. Building on theories of regeneration, co-creation, and local identity, the research will propose an integrative framework that connects place-based heritage with participatory models of sustainable development. Using a multi-sited and participatory methodology, the project will employ ethnographic observation, walking interviews, and participatory photovoice across several Transylvanian villages situated along the Via Transylvania trail. The fieldwork will investigate how communities reinterpret traditions through collaborative practices and how these interactions foster resilience and circular local economies. It is expected that the findings will highlight the transition from preservationist to regenerative mindsets, emphasizing co-creation as both a method and an outcome of tourism development. By articulating a Central–Eastern European perspective on regenerative tourism, the study aims to contribute conceptually and methodologically to current debates on sustainability transitions and education for regenerative development.

Keywords: regenerative tourism, local identity, co-creation, cultural sustainability, Transylvania, participatory research, circular economy

Introduction

Over the past decade, tourism scholarship has evolved beyond the paradigm of sustainability toward more transformative frameworks that emphasize restoration, resilience, and regeneration of socio-ecological systems [1], [6]. *Regenerative tourism* does not merely aim to reduce harm but to generate positive contributions to the vitality of ecosystems and communities. It represents a shift from sustaining what exists to *restoring and enhancing life-supporting systems* through participation, ethics of care, and co-evolution between people and places [11].

In this broader transformation, *local identity* emerges as a key resource. It anchors communities in their heritage and sense of place, while also serving as a dynamic source of creativity and adaptation. As Bramwell and Lane [2] argue, sustainable development increasingly depends on *reflexive governance* - processes through which local actors learn, negotiate, and collectively redefine the meaning of sustainability. In the case of tourism, this involves moving from linear forms of preservation toward *co-creation*, where heritage, tradition, and innovation become intertwined.

Transylvania, with its mosaic of rural landscapes and multicultural legacies, provides a fertile context for exploring these ideas. Once marginalized by post-socialist transitions and depopulation, its villages are now sites of experimentation, where small-scale entrepreneurs, artisans, and community associations design tourism experiences rooted in authenticity, ecological ethics, and reciprocity. These initiatives illustrate how regenerative tourism can operate as both a socio-cultural and economic process - restoring relationships between communities, nature, and visitors.

This paper argues that regenerative tourism in Transylvania reflects a transition *from conservation to co-creation*. Communities are not passive custodians of heritage but active agents of renewal, interpreting local identity through storytelling, crafts, gastronomy, and landscape care. Such practices resonate with broader theories of *resilience and panarchy* [7], [12], emphasizing adaptability and feedback between human and natural systems. They also align with the collaborative ethos of the *sharing and circular economies*, where value is created through networks and participation rather than extraction [4].

The aim of this research is twofold. First, to explore how local identity shapes and is reshaped by regenerative tourism practices in Transylvanian communities. Second, to conceptualize how co-creative initiatives contribute to cultural resilience and circular local economies. The study draws on multi-sited ethnographic and participatory action research (PAR) methods, engaging communities along the Via Transilvanica and other rural destinations as living laboratories of regenerative practice.

By situating these cases within the wider European discourse on sustainability transitions, the paper seeks to articulate a Central - Eastern European perspective on regenerative tourism - one grounded in community agency, hybrid heritage, and the ethics of reciprocity.

Theoretical and Conceptual Framework

a. Regenerative Tourism as a Transformative Paradigm

Regenerative tourism builds upon and moves beyond sustainability. While sustainable tourism aims to mitigate negative impacts, regenerative approaches seek to *restore, renew, and revitalize* socio-ecological systems [1], [6]. This shift repositions destinations not as static spaces to be conserved but as living systems that thrive through reciprocity and adaptive cycles.

According to Holling and Gunderson's [7] concept of *panarchy*, regeneration emerges through continuous feedback between stability and transformation - a balance essential for resilience. Within tourism, this means viewing destinations as part of nested systems, where ecological, social, and cultural regeneration are mutually reinforcing [12].

In practice, regenerative tourism reframes value creation: rather than maximizing consumption, it emphasizes *net-positive outcomes* - improving biodiversity, revitalizing heritage, and enhancing community well-being [1]. This paradigm reflects what Scheyvens and Biddulph [11] describe as *inclusive tourism*, where empowerment, ethics, and equity define the core of responsible development.

b. Local Identity and Cultural Resilience

Local identity - the shared sense of belonging rooted in landscape, memory, and cultural practice - plays a pivotal role in shaping regenerative processes. It acts both as a *foundation* and a *vector* of transformation. Through tourism, communities re-narrate who they are and how they wish to be perceived, negotiating between preservation and innovation [2].

Cultural resilience, as conceptualized within resilience theory [12], refers to the ability of cultural systems to absorb shocks while maintaining core identity and purpose. In Transylvanian rural contexts, this resilience manifests through the revitalization of crafts, traditional architecture, and agro-ecological practices - forms of living heritage that sustain both economy and meaning.

Scholars emphasize that identity is not static but performative [3], [9]. It evolves through acts of storytelling, place-making, and community engagement. Thus, tourism becomes a *space of re-articulation*, where heritage is not frozen in time but regenerated through dialogue between hosts and guests.

c. Co-Creation and Participatory Regeneration

The principle of *co-creation* connects the regenerative paradigm with participatory models of governance and learning. In the *collaborative economy* [4], value emerges through shared creativity and networked participation. Within tourism, co-creation enables communities to design experiences collectively - involving residents, entrepreneurs, NGOs, and visitors as partners rather than separate actors.

This participatory ethos aligns with the educational and ethical dimensions of regeneration. Co-creation enhances *collective learning* and strengthens *social capital*, transforming tourism into a platform for dialogue and shared stewardship [6]. Moreover, it reinforces cultural continuity: by engaging diverse voices, co-creative processes prevent commodification and foster a more authentic expression of local identity.

In regenerative tourism, participation becomes an act of *reclaiming agency*. Communities are not objects of development but co-authors of their futures. Through shared decision-making and experimentation, they embody the shift *from conservation to co-creation* that defines regenerative practice in Transylvanian villages.

Figure 1 presents the conceptual model underpinning this study, outlining how regeneration emerges at the intersection of tourism practices, local identity, and participatory co-creation - a framework that guided the design of the fieldwork and data interpretation.

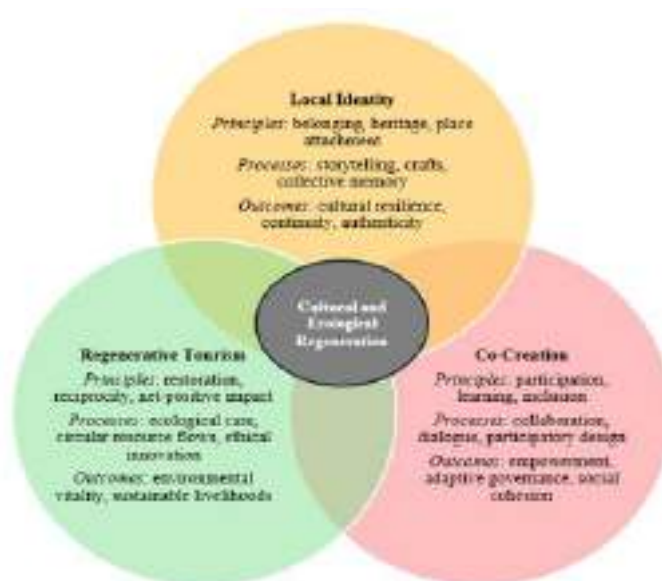


Figure 1. Conceptual model illustrating the interrelations between regenerative tourism, local identity, and co-creation as drivers of cultural and ecological regeneration in Transylvanian communities.

Methodology

The research will adopt a *participatory and interpretive approach*, grounded in the principles of regenerative development and collaborative inquiry. The methodological design will combine *multi-sited ethnography*, *Participatory Action Research (PAR)*, and creative visual methods such as *walking interviews* and *photovoice*. This combination will allow for a holistic understanding of how regeneration is perceived, enacted, and co-created within diverse Transylvanian rural communities.

a. Research Sites and Participants

Fieldwork will be carried out across several communities located along and near the *Via Transilvanica trail*, representing contrasting geographical, cultural, and economic contexts. The selection of sites will follow a purposive sampling logic to include communities with varying degrees of tourism development and civic engagement. Participants will include local entrepreneurs, craft practitioners, educators, community leaders, and residents involved in tourism or cultural initiatives.

The total number of participants is expected to range between 30 and 40, ensuring diversity in age, gender, and professional background. Participation will be voluntary and guided by ethical principles of informed consent, anonymity, and reciprocity.

b. Data Collection Methods

The research will employ four interrelated methods:

1. Multi-sited ethnography

Participant observation will be conducted in each site for a minimum of one week, focusing on everyday practices, cultural events, and interactions between residents and visitors. Field notes will document local expressions of identity, regeneration, and co-creation.

2. Walking interviews

Semi-structured interviews will be carried out while walking through key cultural or ecological landmarks. This mobile approach will enable participants to connect narratives to specific places and to reflect on spatial dimensions of belonging and transformation.

3. Photovoice

Participants will be invited to capture photographs that represent their understanding of regeneration, identity, or change in their community. These visual narratives will later be discussed collectively to co-interpret meanings.

4. Participatory feedback workshops

At the end of the fieldwork, validation sessions will be organized in each community, allowing participants to review preliminary findings and contribute their own interpretations or corrections. These sessions will serve as both a feedback mechanism and a community-learning process.

c. Data Analysis and Validation

Data will be analyzed using *thematic coding and interpretive synthesis*. Emerging themes will be compared across sites to identify convergences and divergences.

Validation will rely on three complementary strategies:

1. *Methodological triangulation*
Comparing data from different methods (interviews, observation, photovoice) and participant groups.
2. *Member checking*
Involving participants in verifying and refining thematic interpretations through feedback workshops.
3. *Reflexive documentation*
Maintaining a researcher's journal to record positionality, emerging insights, and interpretive dilemmas throughout the process.

Supporting materials will include (provided as Annexes A–D):

- *Thematic synthesis sheets* (summarizing emergent categories and evidence sources);
- *Community feedback forms* (collecting participant comments during workshops);
- *Photovoice albums* (with captions and researcher notes);
- *Reflexive journal templates* (for continuous documentation of field interactions).

All these materials will serve as annexes to ensure transparency, reliability, and participatory validity.

d. Ethical Considerations

The research will follow the ethical standards of qualitative inquiry and participatory methods. Informed consent will be obtained prior to each interview, observation, or photographic activity. Participants will retain ownership of their images and narratives, and their contributions will be anonymized in all publications. Ethical approval will be sought from the university's research ethics committee before commencing the fieldwork.

Expected Results and Discussion

The research is expected to reveal how regenerative tourism functions not merely as an economic activity but as a *social and cultural process of renewal*. Preliminary theoretical assumptions suggest that regeneration will emerge through three interdependent dimensions - *local identity, co-creation, and ecological care* - which together produce cultural resilience and circular local economies.

a. From Heritage Preservation to Living Regeneration

It is anticipated that the fieldwork will demonstrate a gradual shift from heritage preservation toward *living regeneration*. Communities are likely to reinterpret their tangible

and intangible heritage as static assets and as *living systems* continuously reactivated through storytelling, crafts, and experiential learning.

This transformation will probably illustrate how regenerative tourism reconnects people to place and redefines authenticity as a process of *relation and renewal* rather than replication of the past.

b. Anticipated Patterns of Co-Creation

The study is expected to highlight co-creation as a *central mechanism of regeneration*. Through participatory initiatives - such as local workshops, cultural routes, and collaborative enterprises - communities will likely move beyond consultation toward shared authorship of experiences.

Such interactions are expected to generate *inclusive forms of governance*, where value creation depends on networks of reciprocity instead of market transactions.

Conflicts or divergences that may arise during co-creative processes will be interpreted not as failures but as feedback loops - essential elements of adaptive learning within regenerative systems.

c. Expected Outcomes for Circular and Regenerative Economies

The findings are expected to show that regenerative tourism supports *micro-circular economies*, where material and symbolic flows are locally retained and reinvested.

Examples may include the reuse of materials, local sourcing of products, and the reintegration of waste into productive cycles.

Beyond material circularity, it is anticipated that *symbolic circularity* - the circulation of stories, skills, and care - will prove equally important for sustaining the vitality of place-based economies.

These dynamics are expected to resonate with the *resilience and panarchy* frameworks [7], [12], suggesting that Transylvanian communities function as adaptive systems capable of renewal through disturbance.

d. Anticipated Theoretical Contributions

Conceptually, the research will contribute to the emerging scholarship on *regenerative tourism* by grounding it in Central - Eastern European contexts, where post-socialist transformations, demographic decline, and cultural hybridity shape distinctive pathways to regeneration.

The study will also refine the *triadic model* of regeneration - linking *identity, co-creation, and care* - by demonstrating how these processes are embedded in everyday community practices. In doing so, it will extend the theoretical dialogue between ecological economics, cultural geography, and sustainability education, providing a multidimensional lens for understanding how regeneration operates at the intersection of culture, ecology, and ethics.

e. Anticipated Practical Implications

Practically, the results are expected to inform *local policy and tourism planning* in rural Transylvania. The findings will likely emphasize the importance of community agency, long-term partnerships, and educational initiatives rooted in regenerative values.

They are also expected to highlight the potential of *universities as facilitators* of regeneration - through participatory education, community-based research, and circular innovation programs.

Ultimately, the study aims to inspire policies that treat tourism not as a driver of consumption, but as a *practice of care, creativity, and ecological reciprocity*.

Conclusions and Implications

This study will seek to advance both theoretical and practical understandings of how regenerative tourism can foster cultural, ecological, and social renewal in Transylvanian rural contexts. It is anticipated that regeneration will be shown not as a static condition but as a *living process* of co-evolution between people, landscapes, and traditions.

Conceptually, the study will offer a framework that integrates *local identity, co-creation, and ecological care* as mutually reinforcing dimensions of regeneration. By situating these processes within post-socialist, multi-ethnic, and place-based contexts, the research will expand existing models of regenerative tourism, which are often derived from Western or insular case studies. The resulting insights will strengthen the theoretical bridge between *cultural geography, sustainability transitions, and regenerative development*.

Methodologically, the paper will contribute to the field by demonstrating how *participatory and visual methods* - such as walking interviews and photovoice - can capture the emotional, sensory, and relational dimensions of regeneration that are often overlooked by conventional tourism research. These methods will highlight the value of community voices and the power of co-created narratives in shaping local strategies for resilience and identity preservation.

Practically, the anticipated findings will inform local governance and educational initiatives that aim to embed regenerative principles into tourism planning and professional training. Universities will be seen as *agents of transformation*, capable of bridging academic knowledge and community practice through participatory education, field-based learning, and capacity-building programs.

Ultimately, this study aims to demonstrate that regeneration is not merely about returning to the past but about *cultivating the conditions for renewal* - where tourism becomes an act of care, learning, and shared responsibility. By grounding these principles in Transylvanian communities, the research will contribute a distinctive Central - Eastern European perspective to the global dialogue on regenerative sustainability.

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Annex A – Thematic Synthesis Sheet

Purpose: To synthesize and cross-validate key themes emerging from different data sources (interviews, observation, photovoice).

Use: During analysis and triangulation.

Template:

Theme / Category	Site(s) where observed	Sources of confirmation	Illustrative quotes / images	Researcher reflections
e.g. Regeneration through crafts	Saschiz, Dârjiu	Interviews I2, I4, Photovoice P3, Observation O1	“We are restoring meaning, not just houses.”	Reflects intergenerational transfer of identity.

Annex B – Community Feedback Form

Purpose: To collect participant reflections during validation workshops or focus-group sessions.

Use: At the end of each community validation event.

Template:

Community: _____

Date: _____

Participant code: _____

1. Which part of the preliminary conclusions do you think best reflects your community's reality?

2. What aspects or experiences do you feel are missing or need correction?

3. Which ideas presented during the workshop could be applied in your community?

4. Any additional comments or observations:

Researcher's synthesis notes:

Anex C – Photovoice Album Sheet

Purpose: To collect and interpret participant-generated images as co-created data.

Use: During fieldwork and feedback discussions.

Template:

Participant code	Photo ID	Participant's caption ("What this image means to me")	Researcher's interpretation	Participant's feedback (during validation)
P01	IMG_032	"The old barn is still alive — it gathers us every autumn."	Symbol of place continuity and seasonal regeneration.	Participant agrees; adds that the barn was rebuilt collectively.

Annex D – Reflexive Researcher Journal

Purpose: To document reflexivity, positionality, and interpretive evolution.

Use: Continuously, throughout the research process.

Template:

Date: _____

Location / Site: _____

1. Context of interaction:

(Brief description of the event, people involved, atmosphere)

2. Observations:

(What was seen, heard, or experienced)

3. Immediate interpretation:

(What meanings or insights are emerging?)

4. Reflexive commentary:

(How might my presence, assumptions, or emotions have influenced the interaction?)

5. Implications for next steps:

FROM MICRO-REGIONAL TO CASE STUDY: DEMOGRAPHIC DYNAMICS AND REVITALIZATION THROUGH RURAL TOURISM IN THE HÂRTIBACIU PLATEAU

Lecturer Talita PASCU Ph.D.

*“Dimitrie Cantemir” University of Târgu Mureș, Dean of Geography Faculty, Romania
Corresponding - Pascu Talita: pascutalita15@gmail.com*

Abstract

This article examines the complex relationship between depopulation and rural tourism, analysing how tourism can function as a driver for socio-economic and demographic revitalization in the Hârtibaciu Plateau. The region, located in south-central Transylvania, is defined by a unique symbiosis of natural and multicultural anthropogenic heritage, but faces a dual challenge: (1) significant demographic decline, marked by an aging population and depopulation, and (2) a slow post-communist economic restructuring that accentuates its isolation. To demonstrate this potential concretely, the paper uses a mixed-methods approach, combining statistical analysis with a qualitative case study of the Șeica Mare commune. This municipality was chosen for its historical relevance and because it faithfully reflects the entire region's challenges, including a significant population decline and an aging demographic structure. A SWOT analysis highlights the region's strengths (authenticity, Saxon heritage, local products), weaknesses (deficient transport infrastructure, inefficient promotion, depopulation), opportunities (growing demand for rural/eco-tourism, European funds), and threats (workforce migration, heritage degradation). The article concludes that rural tourism, though incipient, already has a real positive impact. It is a viable solution for socio-economic revitalization, acting as a factor for stabilizing the workforce, conserving cultural heritage, and adding value to local agriculture. The study provides strategic recommendations for integrated infrastructure development, human resource training, and sustainable community-based conservation to ensure the long-term revitalization of the region.

Keywords: Hârtibaciu Plateau, rural tourism, depopulation, demographic dynamics, sustainable development, revitalization, cultural heritage, SWOT analysis

Introduction

The Hârtibaciu Plateau, situated in the geographical centre of Romania, in southern Transylvania, represents far more than a mere geomorphological unit. In recent decades, it has increasingly come to be understood as a “cultural landscape”, shaped by a long-standing interaction between diverse communities and the natural environment. The region is characterized by a rare harmony: a well-preserved natural setting — reflected in the extensive network of Natura 2000 protected sites — and a multicultural anthropogenic heritage, where Saxon, Romanian, and Hungarian influences coexist and complement one another.

Medieval fortified churches, vernacular architecture, traditional crafts, and local gastronomy constitute a valuable cultural ensemble which, although still insufficiently capitalized, holds considerable potential for tourism development. Behind these elements of attractiveness, however, lies a fragile socio-economic reality. The Hârtibaciu Plateau is currently undergoing a profound transformation shaped by two interrelated challenges.

The first is a structural demographic decline, manifested in the persistent decrease of the population and the accelerated ageing of rural communities. Depopulation is no longer merely a statistical indicator; it has become visible in everyday life — in abandoned houses, the out-migration of young people, and the gradual loss of community memory [1]. The second challenge stems from the difficulties associated with the post-communist economic transition. The shift from a planned economy to a market-based system left many localities on the margins of investment flows, maintaining agriculture as the dominant economic activity but one unable to sustain a stable young workforce. Limited economic opportunities have fuelled migration and further reinforced demographic decline [2].

Within this context, identifying effective strategies for rural regeneration becomes increasingly urgent. Tourism — particularly rural, cultural, and agro-tourism — emerges as a strategic option not only because of its economic potential, but also because it relies on existing, place-specific resources. By valorizing traditional practices, cultural heritage, and the rural landscape, tourism can contribute to demographic stabilization and socio-economic revitalization.

To assess the feasibility of this approach, the article shifts the analytical scale from the macro-regional level to the local one, through a case study of the Șeica Mare commune. This choice is deliberate: Șeica Mare exemplifies the main demographic and socio-economic dynamics characteristic of the wider plateau, making it a useful “microcosm” for understanding regional processes. By examining demographic trends and local tourism resources, the case study provides a concrete framework for analysing how tourism may contribute to the regeneration of a territory under pressure from depopulation and ongoing structural change.

Macro-Regional Context: Demographic Dynamics of the Hârtibaciu Plateau

Understanding the need for revitalization in the Hârtibaciu Plateau requires moving beyond its picturesque landscapes and focusing instead on the demographic realities that shape everyday life in the region. The analysis of aggregated demographic data reveals a pattern of sustained decline, a phenomenon that represents far more than an abstract statistical trend. It reflects communities shrinking under the combined pressures of migration, ageing, and economic restructuring.

At the core of this demographic contraction lies a structural cause: the persistent out-migration of young people. Whether moving to nearby urban centres or emigrating abroad, young adults leave behind villages with diminishing vitality and an increasingly imbalanced population structure [1]. This depopulation is not a recent occurrence. Rather, it has deepened steadily, with population density visibly decreasing particularly after 1977. The effects of these changes are most clearly seen in the region’s traditional centres of stability.

Agnita, the only urban settlement in the area, serves as a telling example. According to data from the National Institute of Statistics (INS), the town’s population decreased from 12,968 inhabitants in 1992 to 12,261 in 2014 and 10,912 in 2025. The downward trend intensified after 2007, transforming Agnita from a local pole of attraction into a net source of out-migration. The decline of the town reverberates throughout the surrounding villages, weakening their economic and institutional support systems.

Although the overall trend is one of demographic deterioration, the plateau does not present a uniform demographic landscape. Rather, micro-regional variations offer important insights. The analysis of population changes between 1992 and 2025 shows a complex dynamic. Some communes, such as Brădeni or Șeica Mare, continue to face significant demographic challenges and structural ageing. Others, unexpectedly, display signs of resilience. The commune of Nocrich is an illustrative case: after a sustained decline until 1997, its population gradually increased from 2,667 inhabitants in 1992 to over 3,200 in 2014, reaching 3,553 by 2025 [3]. Similar, though more moderate, patterns can be observed in Moșna or Albești. This “revitalization” is less a result of natural population growth and more a consequence of urban-to-rural migration, often involving individuals in the second half of their life cycle who seek a quieter, more affordable environment.

Beyond total population numbers, the age structure sends the most alarming signal. The Hârtibaciu Plateau exhibits a pronounced ageing process, especially in its southern communes. Comparative analysis of age pyramids reveals a striking shift: whereas two decades ago, the population structure displayed a solid base of young and active individuals, recent data show a disproportionate concentration of inhabitants aged 45–70. This narrowing base of younger cohorts points to declining fertility rates and limited retention of young families. In Șeica Mare, for example, the share of residents aged 60 and over reaches 23.62% in 2025 [4]. Such an imbalance raises concerns about the availability of labour for future development initiatives and about the broader socio-economic sustainability of many villages.

These findings underscore a critical conclusion: the demographic challenges faced by the Hârtibaciu Plateau are not isolated anomalies but defining structural features of the region. Depopulation, driven primarily by youth migration and limited economic opportunities, has generated a self-reinforcing cycle of isolation. Ageing and underpopulated villages represent not only social and demographic issues but also economic constraints. Traditional development models centred exclusively on agriculture no longer suffice to sustain community life or to attract younger generations. In this fragile context, any revitalization strategy must begin with a clear acknowledgement of demographic reality. New, place-sensitive development pathways are required—pathways that can transform the region’s cultural and natural assets into reasons for residents to remain or to return. Tourism, as explored in the subsequent sections, emerges as one such pathway, offering both economic alternatives and opportunities to strengthen local identity in the face of demographic decline.

Case Study: Șeica Mare Commune – Mirror of a Plateau in Transformation

To move from the general dynamics of the Hârtibaciu Plateau to the lived reality of its communities, the analysis focuses on a detailed case study of the Șeica Mare commune. This choice is deliberate: Șeica Mare encapsulates many of the demographic, social, and economic transformations characteristic of the entire region. It therefore functions as a valuable analytical laboratory—a micro-scale setting in which the broader regional patterns can be observed, interpreted, and understood.

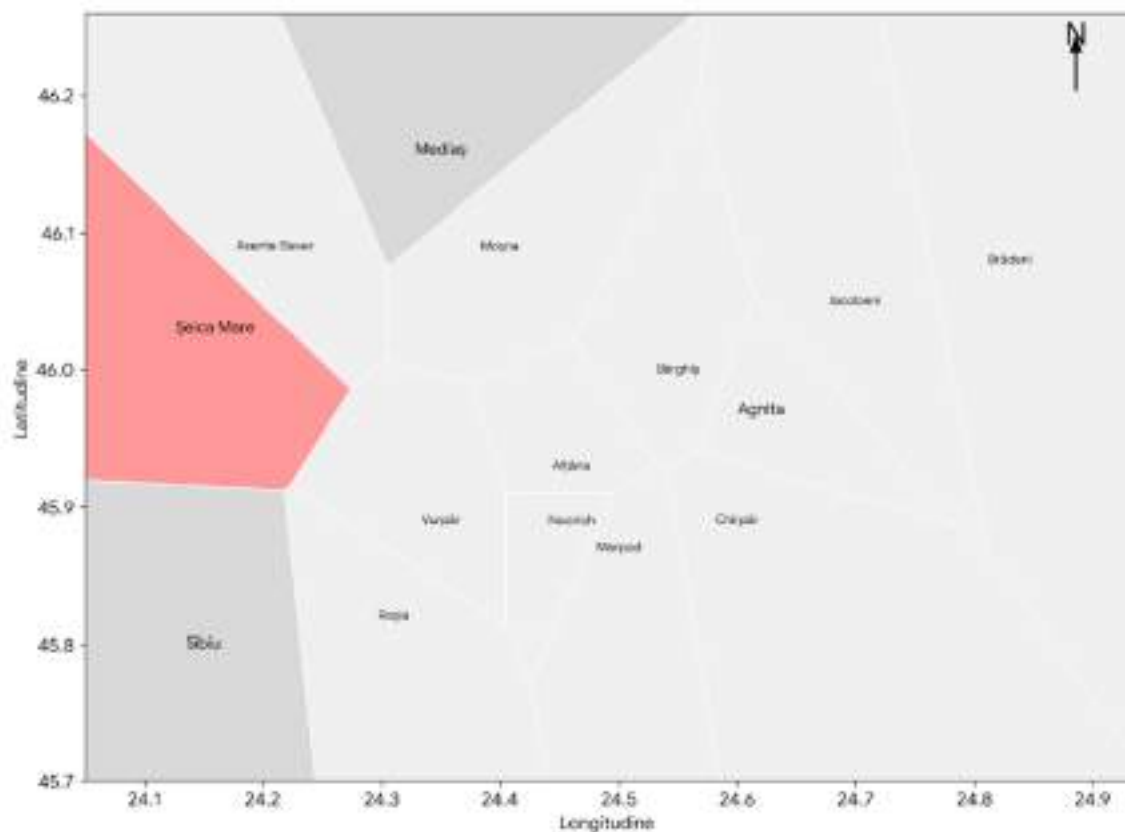


Figure 1. Schematic Map of the Study Area.

The methodological approach adopted for this case study is mixed, combining quantitative demographic analysis with a qualitative assessment of local resources and strategic planning documents. Long-term statistical data from the National Institute of Statistics (1990–2025) provide an objective view of population change, while field observations and documentation offer insights into how local heritage, landscapes, and socio-economic structures shape the commune’s development potential. This integrated approach makes it possible to examine not only the scale of demographic decline, but also the mechanisms through which tourism may counteract it.

Table 1. Key Demographic Indicators – Seica Mare Commune

Indicator	Year 1996	Year 2025	Evolution (%)
Total Population	5,235	4,525	▼ -13.56%
Share of population 60+ years	7.57%	23.62%	▲ +212.02%
Birth Rate (annual average)	31 pers.	46 pers.	▲ +48.39%
Natural Balance	Positive	Negative	▼ Decline

(Source: INS, 2025)

Recent data for 2025 reveal a demographic structure marked by accelerated ageing. While the official number of elderly residents (23.62% aged 60+) is already high, it likely underestimates the real situation due to the mobility of the younger population. Many young adults maintain official residence in the commune, even while living and working elsewhere—

a phenomenon often referred to as the “ghost population”. As a result, the effective working-age population is smaller than the statistics suggest. Although the annual number of live births (46) appears relatively stable, it is insufficient to offset mortality and migration. The negative natural balance and persistent out-migration of young people reinforce one another, contributing to an ageing and increasingly dependent population structure. This demographic configuration raises concerns about the availability of labour for future tourism initiatives and about the commune’s long-term social resilience [5].

Tourism Resources: A Rich but Underutilized Heritage

If demographic indicators paint a picture dominated by decline, the catalogue of local tourism resources provides an important counterbalance. Şeica Mare possesses a diverse and valuable heritage—cultural, historical, intangible, and natural—which, if strategically activated, can support tourism development and contribute to socio-economic revitalization.

a. Built Cultural Heritage

The most prominent heritage asset is the Fortified Church of Şeica Mare, a 15th-century monument that preserves the memory of the Saxon community and represents a key element of Transylvania’s architectural landscape [6]. Nearby, Buia Castle adds historical depth and symbolic significance. Dating back to the 14th century, the castle is associated in historical documents with the rule of Michael the Brave (Mihai Viteazul), adding national historical value to the site [7; 4].

b. Intangible and Memorial Heritage

The cultural heritage of the commune is enriched by sites connected to notable historical figures. The village of Buia is the birthplace of the mathematician Farkas Bolyai and is closely linked to the life of his son, János Bolyai—one of the founders of non-Euclidean geometry. The existence of a small museum dedicated to the Bolyai family creates opportunities for niche cultural and scientific tourism [4]. Local traditions also remain visible through the “Florile Visei” Folk Ensemble, whose performances help preserve and transmit regional identity.

c. Natural Heritage

Şeica Mare is integrated into the Natura 2000 site ROSPA0027 *Dealurile Homoroadelor*, confirming the ecological value of its semi-natural grasslands, deciduous forests, and traditional agricultural landscapes. These features provide excellent conditions for ecotourism, hiking, birdwatching, and landscape-based recreation [8].

The Duality of Local Development: Potential vs. Reality

The commune presents a striking juxtaposition: significant cultural and natural resources on one hand, and visible signs of decline on the other.



(a) *The fortified church, symbol of enduring heritage;*



(b) *Characteristic landscape of the "Dealurile Homoroadelor" Natura 2000 site;*



(c) *Best practice example: vernacular architecture revitalized through tourism;*



(d) *Effects of depopulation: degradation of abandoned built stock.*

Figure 2. The Antithesis of Local Development: Potential vs. Reality.

Image sources: a – kirchenburgen.org; b – Asociația Carpaterra; c - booking.com; d – actualdecluj.ro

While some properties have been restored and repurposed for tourism—exemplifying best practices in heritage conservation—others remain abandoned, deteriorating due to migration and lack of maintenance. This duality underscores the urgency of valorizing tourism as a tool not only for economic development but also for heritage preservation. Moreover, the profile of emerging visitors indicates promising trends. Șeica Mare increasingly appeals to culturally motivated travellers seeking authenticity, as well as to digital nomads who value the tranquillity and sense of “creative retreat” offered by rural Transylvania. These visitor segments suggest that the commune’s isolation—which historically represented a disadvantage—can become an asset when aligned with contemporary lifestyle trends.

SWOT Analysis and Discussions: Between Latent Potential and Structural Realities

A simple inventory of tourism resources is not sufficient to grasp the complexity of the developmental challenges facing the Hârtibaciu Plateau. What is needed is a strategic diagnostic tool capable of capturing the interplay between the region’s assets and vulnerabilities. The SWOT analysis presented below performs this role by examining the strengths, weaknesses,

opportunities, and threats that shape the tourism potential of the region and reflect the realities observed in the Șeica Mare case study.

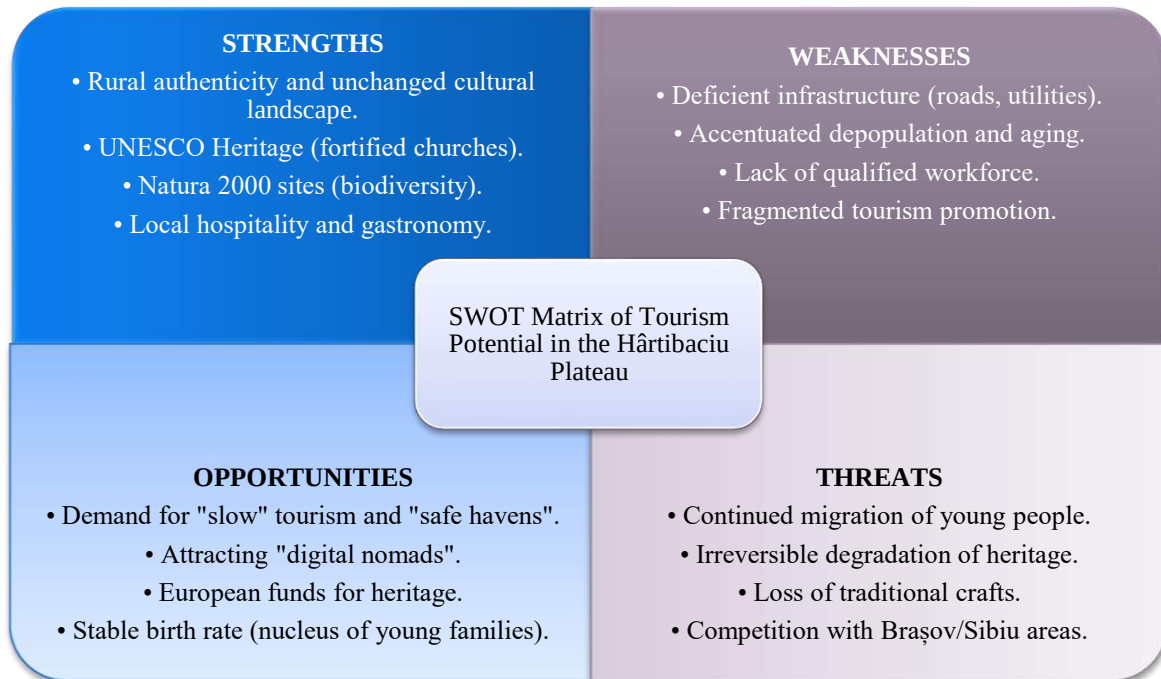


Figure 3. SWOT Matrix of Tourism Potential in the Hârtibaciu Plateau

Strengths

The region's strengths form a compelling foundation for future revitalization strategies. Perhaps the most distinctive asset is the rural authenticity that has been preserved over centuries. The built heritage associated with the Transylvanian Saxons—including fortified churches, several of which are protected as UNESCO World Heritage Sites such as those in Biertan, Valea Viilor, or Saschiz—constitutes a major competitive advantage [9]. This architectural legacy is complemented by vibrant local traditions, vernacular crafts, and culinary practices [10].

Weaknesses

Despite these advantages, the region faces structural weaknesses that significantly constrain tourism development. The most persistent and problematic issue is the state of physical infrastructure. Many county and communal roads are in poor condition, and several villages still lack basic utilities such as sewage systems or running water. These infrastructural deficits deter both potential investors and tourists, limiting accessibility and diminishing the overall visitor experience [4].

Opportunities

Several opportunities offer promising avenues for tourism-driven revitalization. Global tourism trends increasingly favour rural, ecological, and cultural experiences, particularly in the aftermath of the COVID-19 pandemic, which strengthened the preference for authenticity, safety, and nature-based activities [11]. The availability of European funds dedicated to rural development and heritage conservation represents another important opportunity. Furthermore,

the rise of remote work and digital mobility creates new opportunities for attracting digital nomads and creative professionals.

Threats

Despite these opportunities, several threats could hinder the long-term success of tourism development. Continuous labour migration represents a critical risk, as it may lead to shortages of staff qualified for tourism services [12]. The ongoing degradation of built heritage is another major concern; abandoned and deteriorating properties may be lost irreversibly if not restored in time.

The synthesis of SWOT elements leads to a central argument: demographic decline and limited economic diversification are mutually reinforcing, creating a cycle of depopulation and stagnation. To break this cycle, development strategies must mobilize tourism as a stabilizing mechanism. First, tourism can help stabilize the local workforce by generating jobs in accommodation and complementary services [13]. Second, tourism offers a sustainable mechanism for heritage preservation; when historical buildings are integrated into economic activities, local actors gain both motivation and resources to conserve them [14]. Third, tourism enhances the value of local agriculture by creating new markets for small farmers [4].

Conclusions and Strategic Recommendations: A Roadmap for the Future

The findings of this study confirm that the Hârtibaciu Plateau stands at a critical crossroads. Depopulation is not merely a theoretical concern but a lived reality, shaped by persistent youth migration and accelerated demographic ageing. Historical examples from localities such as Alțâna illustrate how the large-scale departure of Transylvanian Saxons disrupted longstanding community structures, leaving behind both vulnerable heritage assets and a pressing need to redefine local identity.

Despite these challenges, the research shows that the region is not destined for irreversible decline. Tourism — particularly in its rural, cultural, and agro-tourism forms — emerges as a viable means of generating tangible socio-economic benefits. In addition, agro-tourism provides a unique opportunity to fully valorize rural households, enabling families to diversify their incomes without requiring substantial capital investment [15].

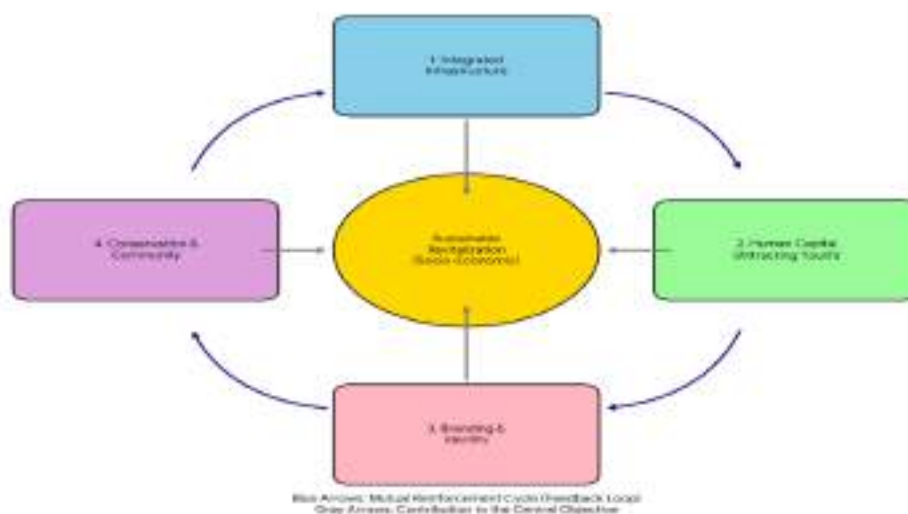


Figure 4. Strategic Model for Integrated Revitalization of the Hârtibaciu Plateau

Based on these insights, the following strategic directions outline a pathway for revitalization:

1. *Integrated Infrastructure Development* -Modern, reliable infrastructure — including utilities, transport links, and digital connectivity — is the indispensable foundation for sustainable development. Enhanced broadband access is particularly essential for supporting tourism entrepreneurs and for attracting remote workers.
2. *Human Capital Development and Community Engagement* - Attracting and retaining young residents is crucial. [16] This can be supported by offering training programmes in hospitality, heritage management, and digital competencies.
3. *Identity Branding and Cultural Valorization* - A coherent regional brand should reflect the plateau's unique combination of Saxon heritage, Romanian and Hungarian cultural influences, and ecological landscapes. Promotion should highlight intangible cultural resources and local narratives. [17; 18]
4. *Conservation and Community-Based Stewardship* - Tourism revenues should be reinvested in the preservation of built heritage. Sustainable models that involve local communities — such as community-run guesthouses — can help ensure that conservation efforts remain authentic. [19]
5. *Strengthening the Agro-Tourism Product* - Agro-tourism should be promoted as a flagship development model. Activities such as milking, haymaking, or traditional cooking can provide immersive experiences that differentiate the region from other rural destinations.

The integrated model proposed in this study emphasizes the circular and mutually reinforcing nature of the development process. Infrastructure improvements attract new residents; their presence strengthens local identity; increased tourism revenues fund conservation; and these, in turn, enhance the region's attractiveness. In conclusion, the future of the Hârtibaciu Plateau depends on its capacity to reinvent itself without losing its cultural depth and rural essence.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author used Gemini for linguistic support to improve the readability and language of the manuscript. After using this tool/service, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication.

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Image sources:

1. Fortified Church of Șeica Mică: Wikipedia.
2. Volcanic landscape: Carpaterra.org.
3. Hotel accommodation: Booking.com.
4. Degraded housing: Actual de Cluj.

HAIL SUPPRESSION STRATEGIES IN THE MIDDLE MUREȘ WATERSHED

Lecturer Marius CIGHER Ph.D.

*"Dimitrie Cantemir" University of Târgu Mureș, Faculty of Geography, Romania
Corresponding author: Marius Cigher: cighermarius@gmail.com*

Abstract

The activities of hail suppression localized or large-scale precipitation enhancement, and fog dissipation are complex, combining research functions with operational protection against disasters caused by dangerous or harmful meteorological phenomena in the context of global climate change.

Hailfall Combating Unit (UCCG) Mureș aims to protect a total area of 330,000 hectares, largely consisting of orchards and vineyards. Operations began in spring 2022 and run from April 15 to October 15. Hail-control actions started in late April, when — for the first time since the system was implemented in Romania — interventions were carried out to counteract the hydrometeor across several control units, including Mureș.

The case study presented demonstrates the effectiveness of this system, with no destructive effects reported in the agricultural areas within the protection zone. Its effectiveness is supported by the performance of the embedded systems: reliable information from the national meteorological radar network, forecast bulletins provided by the National Meteorological Administration (acronym ANM) and internal sources (the integrated center in Iași), the absence of air-traffic restrictions, and, not least, the contribution of human resources, both at the command center and at the launch sites.

Keywords: hail suppression, meteorological radar, forecast, command center, launch sites, protection zone

1. Introduction

Hail mitigation efforts largely focus on cloud seeding, a technique that disperses artificial ice nuclei into storm clouds to promote the formation of numerous smaller hailstones that are more likely to melt before reaching the ground [1]. This is typically done by releasing substances such as silver iodide using aircraft, rockets, ground-based generators, or cannons, which either enhance ice crystal formation or influence cloud behaviour. Additional protective approaches include installing anti-hail nets over crops and using so-called anti-hail guns that generate shockwaves. The primary hail suppression method involves injecting seeding materials, such as silver iodide, into thunderstorms, where they function as artificial ice nuclei.

The particles introduced form many artificial hail embryos that compete with naturally occurring ones for supercooled water [2]. This competition leads to the development of many smaller hailstones rather than a few large, damaging ones. Cloud seeding can also trigger precipitation earlier in the storm's life cycle, thereby decreasing the amount of moisture available for hail growth [2]. Delivery methods can be aircraft disperse seeding agents directly within storm clouds, rockets or high-powered cannons launch the materials from the ground into the clouds or ground-based generators emit silver iodide into the atmosphere, allowing storms to absorb the particles as they develop.

2. UCCG (Hailfall Combating Unit) Mures

For the hail suppression program in the middle Mureș River basin, rockets were selected as the deployment method. These projectiles deliver silver iodide, which serves as a condensation nucleus. The Anti-Hail system consists of a central command center in Vidrasău, Mureș County, and 16 launch sites grouped into three sectors: Mureș North (six sites), Mureș South (four sites), and Alba (six sites) (Figure 1).

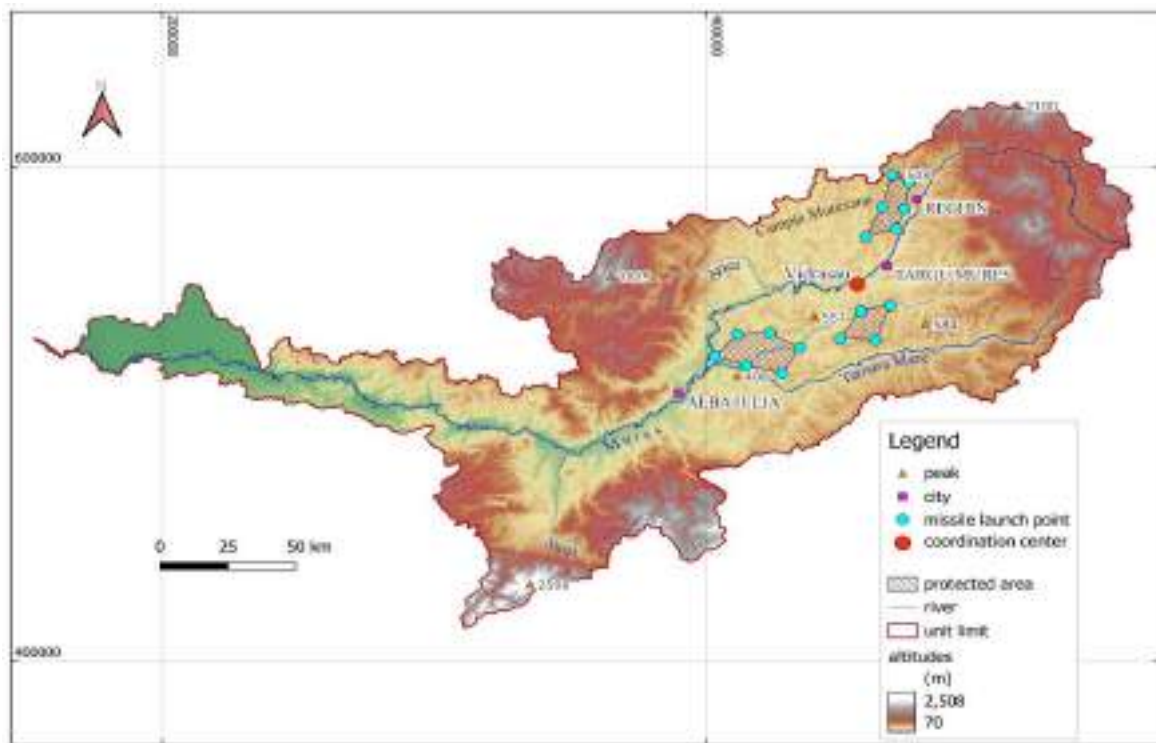


Figure 1. Hail suppression system from the middle Mures watershed (CRS: stereo 70)

The Command Point serves as the logistical hub where operational decisions are taken based on meteorological data supplied by the internal network, including the Integrated Center in Iași, the National Meteorological Agency's radar systems, and established internal procedures. Personnel are the key asset of this center, as trained staff are responsible for managing both pre-launch and post-launch operations. Missile launches are carried out at the Launch Points by operators who provide continuous, 24-hour coverage. Launch commands are communicated from the Command Point to the Launch Points by telephone (Figure 2).



Figure 2. Command Point (left image) and Launch Point (right image) with operators and a missile launch unit - Larma 1 [4]

To ensure the uninterrupted execution of combat operations, well-defined collaboration protocols are established with the Integrated Center in Iași. This center, in turn, maintains a critical coordination agreement with the Romanian Air Traffic Services Administration (acronym ROMATSA) to prevent any airspace-related incidents.

Specifically, the system was established primarily to safeguard orchard and vineyard zones, particularly those designated as strict protection areas (Figure 3).

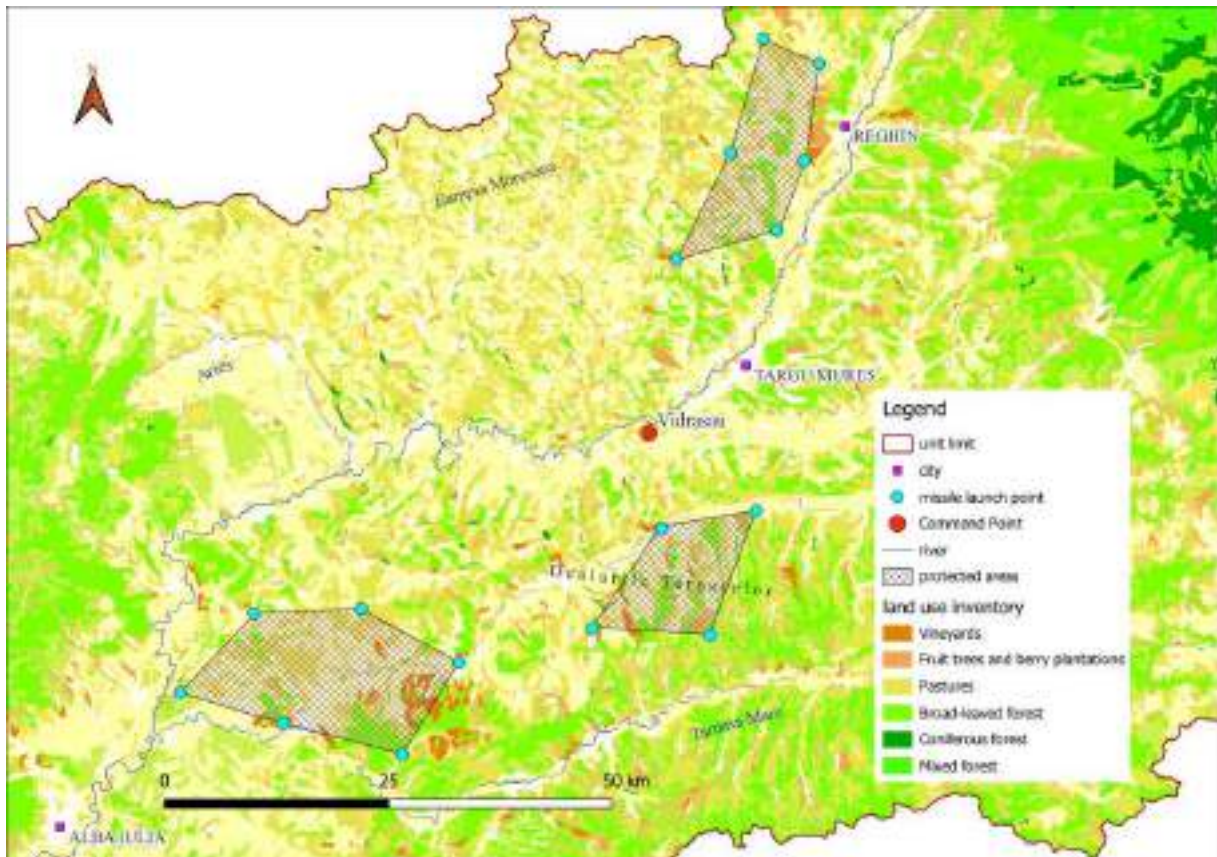


Figure 3. Land cover and land use inventory in the middle Mureș watershed - CORINE Land Cover 2018, vector data from [5]

In 2020, at the beginning of the program, Mureș Hailfall Combating Unit (UCCG) aim to protect a total area of 321,497 hectares (see Table 1).

Table 1. UCCG Mures total area to be protected in 2020 (ha)

Combating Unit / group	Numbers of Launch Point in 2019	Protected areas in 2019 (ha)	Numbers of Launch Point in 2020	Protected areas in 2020 (ha)
UCCG Mures	-	-	16	321497
Mureș North	-	-	6	104873
Mureș South	-	-	4	127873
alba	-	-	6	88751

The hail control system in the middle Mureș River basin became operational in 2022, initially with ten launch sites within the Mureș Nord and Mureș Sud units. Its operational period runs from April 15 to October 15. Starting in 2024, the launch sites in the Alba Group were also activated. Currently, the system's operation is suspended nationwide pending a new environmental impact assessment and the completion of the approval process.

Table 2 summarizes the hail suppression activities carried out from 2022 to 2024, in Mures North and Mures South groups.

Table 2. Synthetic data on hail suppression activities in the period 2022-2024

Combating Unit / group	number of launching points	number of actions	Number of cloud units	number of rockets
2022				
Mures North	6	18	72	337
Mures South	4			
2023	6			
Mures North	4	28	57	319
Mures South	6			
2024	4			
Mures North	6	4	10	66
Mures South	4			

*Data from [6]

3. Conclusions

Hail suppression in the middle Mureș River basin relies on cloud seeding using silver iodide, which acts as a condensation nucleus to promote ice crystal formation and reduce hail development. The seeding agent is delivered via rockets launched from strategically positioned sites, coordinated by a central command center that monitors meteorological data, including radar observations and weather forecasts. Operations are conducted during periods of high hail risk, typically between April and October. The effectiveness of the system is assessed by measuring the area protected, reductions in hail size and frequency, and the resulting decrease in crop damage. Coordination with meteorological agencies and aviation authorities ensures safe and efficient deployment of the system. The Mureș Hail Control Unit protected an area of approximately 154,000 hectares in Mureș County using ten launch sites located in the localities of Câmpenița, Glodeni, Breaza, Fărăgău, Logig, Gorenii, Șoimuș, Cund, Căpâlna de Sus, and Delenii. Within the Mureș UCCG, operations were carried out against 139 convective cells with developing hail, resulting in the use of a total of 722 RAG units.

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STEPS TOWARDS SCARPS GEOCONSERVATION - CASE STUDY IN ROMANIA

Lecturer Radu NEGRU Ph.D.

*“Dimitrie Cantemir” University of Târgu Mureș, Faculty of Geography, Romania
Corresponding - Radu Negru: negrurg@yahoo.com*

Abstract

The paper explores scarps geo-conservation strategies in Romania. Geoconservation refers to the measures and policies aimed at safeguarding geological and geomorphological features from damage or degradation. Glămeia Scarp, a not protected area from Romania, was assessed to be proposed for protection. Declaring a protected area in Romania involves several steps, guided by the national legislation (Emergency Ordinance 57/2007): assessment of the site, community and stakeholder engagement, legislation review, proposal development and submission, evaluation, approval and declaration, management and monitoring. By following these steps, a Local Council from Romania can effectively create a protected area of local interest, ensuring the protection and sustainable management of the geological and geomorphological features. If the decision makers (Boșorod Council) and local community will understand the importance of Glămeia Scarp, the protection could be obtained by declaring Glameia Scarp as a natural protected area of local interest.

Keywords: geoconservation, scarps, Glămeia Scarp, legislatio

Introduction

The purpose of this study is to present the specific steps toward geoconservation of scarps in Romania, with emphasis on the Glămeia Scarp, known locally under the same name and currently lacking a protective status.

Geoconservation is defined by Sharples [1] as the conservation of geological and geomorphological elements, processes, and landscapes. It involves legal, administrative, and management actions aimed at mitigating anthropogenic and environmental impacts [2,3]. In Romania, conservation refers to a set of measures intended to maintain or restore natural habitats, species, and elements of geological, geomorphological, or landscape value [4].

Emergency Ordinance 57/2007 [4] is the main legislative instrument guiding nature protection. Article 5(1) defines four categories of protected areas: national, international, community [5] and county or local interest. Geological and geomorphological features may be formally protected by establishing suitably delimited protected areas (Articles 41, 42, 46).

Under Article 8(1)(d), protected areas of county or local interest are established by decisions of the respective county or local councils [5]. A scientific documentation constitutes the basis for such proposals (Article 8(6)). The legal model for establishing protected areas (Article 10) stresses the importance of integrating community interests and traditional land-use practices. Landowners and relevant stakeholders must be informed and consulted (Article 12), while

newly designated protected areas must be included in cadastral and spatial planning documents (Article 15).

This paper aims to show that the protection of Glămeia Scarp is feasible, highlighting its geological and geomorphological significance and the legal framework that supports its conservation.

Methodology

Declaring a protected area in Romania involves several steps, guided by the national legislation [4]: assessment of the site, stakeholder and community engagement, proposal development and submission to competent authorities, legislative and administrative procedure.

Results

The evaluation of the site includes the geographical positioning, site limits, access routes, safety of visitation, geological and geomorphological elements.

Glameia Scarp is located at the contact of the Hateg-Strei Depression [6] with Sebeş Mountains (Fig.1), between Bobaia and Ocoliş valleys (Fig. 4). From an administrative point of view, the scarp lies on the territory of the Bosorod Commune. The main scarp has the coordinates 45°41'18.90"N, 23° 6'9.67"E (Fig. 1).



Fig.1. Location of the Glămeia Scarp (white star) within the Hateg-Strei Depression (Google Earth Pro).

The area called Glămeia, includes several steep slopes, having an area of 63000 m², a length of 1.12 km and a width of up to 100 m. In the western end of the escarpments, we have found a formerly building stone quarry. The permission to visit is not required at present. We found clean, clear rock faces but also heavily vegetated. The presence of shrubs and vegetation to lower rock face is frequent. The Glămeia Scarp would benefit considerably from vegetation clearance. The limits of the scarps are marked below, on the satelitary immagine (Fig. 2).



Fig.2. Satelitary image with the limits of Glameia Scarp and access ways (Google Earth Pro).

The access to Glămeia Scarp (Fig.2) is possible on the road 668A, towards Boșorod Village. At the entrance in the Boșorod Village, on the left, is București Street towards Bobaia Village. After about 400 m, on the left side of the București Street, the Glameia Scarp will be visible (Fig. 3). Further, access will be possible on the shepards paths or on the non-modernized roads. The scarps are located a few hundred meters from the street. Roadside parking is possible along București Street.

Basic protective equipment (boots, helmet) is recommended, because of the uneven ground, possible rockfalls near the scarps and debris.



Fig. 3. The main scarp from Glameia area.

The consultation of the specialized literature and the activity carried out in the field allowed the identification of the main geological and geomorphological elements and processes of the Glămeia Scarp (Table 1).

The escarpment, developed on Middle Miocene sedimentary deposits, presents an ENE–WSW alignment, with strata generally dipping NW, characteristic of a monocline structure [7]. This structure influenced the drainage patterns of the consequent (Luncani) and subsequent valleys (Bobaia and Ocoliș). Glămeia Scarp forms the scarp of the Surîla Hill cuesta (437.7 m).

This cuesta was determined by the deepening of the subsequent Bobaia and Ocoliș valleys (Fig. 4, right).

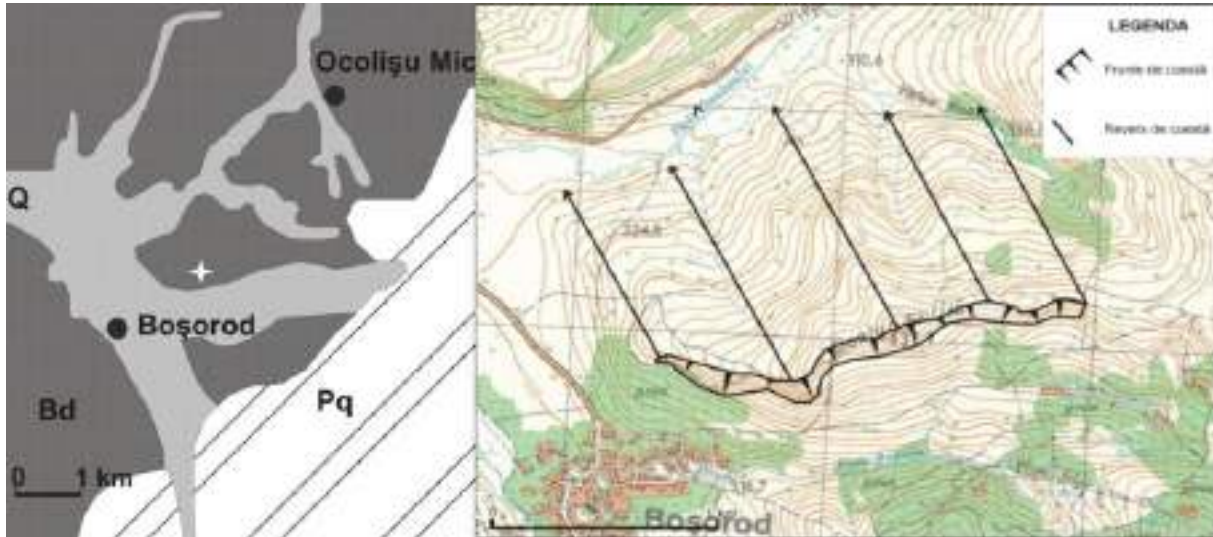


Fig. 4. Geological sketch (left) (Pq - Metamorphic; Bd - Badenian; Q – Quaternary) [Codarcea et al., 1968] and fragment of the topographic map (right) with the sketch of the elements of the cuesta from the Surila Hill (topographic map L-34-083-C-c).

The lithology is represented by sandstones, conglomerates and sandy clays with calcareous cement, accumulated in a marine environment, in Middle Miocene (Badenian) [Gheorghiu et al., 1962]. The fossils identified are represented by lamellibranchiate and rhodolite's [8] (Fig.5).



Fig. 5. Rhodolites located in the upper part of the sedimentary succession of the Glameia Scarp (left) and conglomerate with fragments of lamellibranchiate (right).

The dominant geomorphological processes are represented by weathering, rockfalls (Fig. 3) and landslides (Fig. 6a), their products forming an accumulation glaciis (Fig. 3). The differentiated erosion determined the formation of structural shelves and overhangs (Fig. 6b). The calcareous cement of the sandstones and conglomerates favored the chemical weathering and the development of the sinkholes, in the interfluvial sector (Fig. 6c). The anthropic relief is represented by the "Baia Glămeii" Cave formed by the extraction of the building stone by the locals from Boșorod (Fig. 6d). The quarry is probably one source of building stone used for the Dacian fortresses in the Sebes Mountains [9].

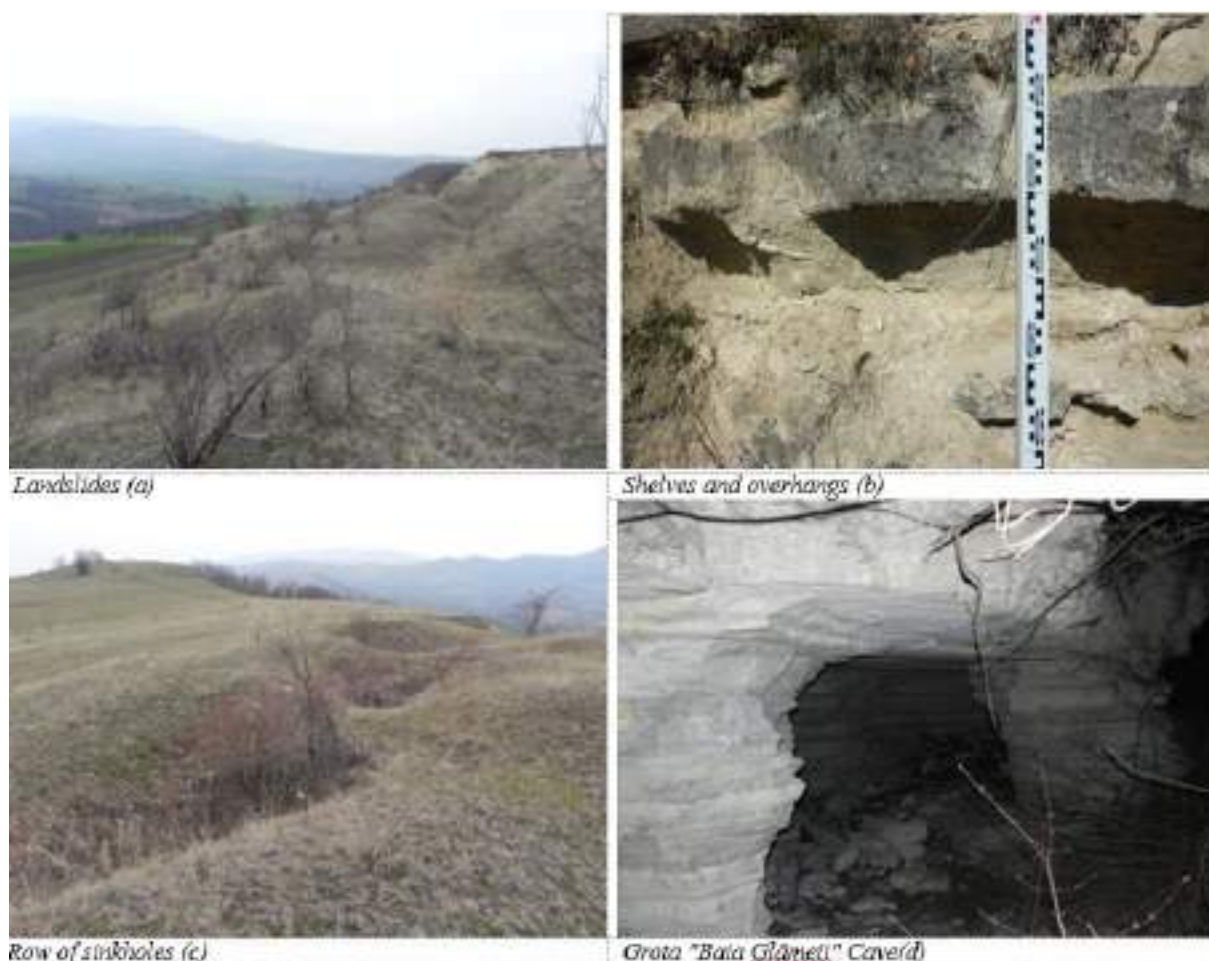


Figure 6. illustrates representative geomorphological features of the study area, including slope instability expressed as landslides (a), erosion-induced shelves and overhangs within sedimentary deposits (b), a linear alignment of sinkholes indicative of subsurface karst processes (c), and the Grotta “Baia Glămeii” Cave (d), highlighting the influence of lithology and groundwater dynamics on landscape evolution.

Table 1. Inventory of the main geological and geomorphological elements of the Glameia Escarpment.

Geological and geomorphological assessment	
Lithology	conglomerates, sandstones, sandy mudstones with carbonatic cement
Geological structures	monoclinial structure
Fossils	rhodolites, bivalves
Ages represented	Middle Miocene, Quaternary
Morphostructures	cuesta scarp, structural surfaces
Morphogenetic systems	slope, karst
Erosional landforms	scarps, dolina
Accumulation landforms	Glacis
Anthropic landforms	“Baia Glămeii” cave and quarry
Present day processes	weathering, rock falls, slides

Successful geoconservation initiatives depend not only on scientific assessment and legal frameworks but also on the acceptance and active involvement of local communities and stakeholders. In the case of the Glămeia Scarp, community engagement is particularly important

given the predominance of traditional land-use practices, fragmented land ownership, and the potential role of geotourism in local socio-economic development [11].

Stakeholder engagement activities focused on identifying land ownership through the consultation of cadastral and property maps (Fig. 7), facilitating direct dialogue with residents (Fig. 7) during field visits, and communicating the scientific and cultural significance of the escarpment. Local knowledge, particularly concerning the anthropogenic feature known as the “Baia Glămeii” Cave, was integrated into the assessment process, contributing to a more comprehensive understanding of the site’s historical and geomorphological context [12].

Feedback Collection comprise collect feedback, address concerns, and incorporate suggestions from the community and stakeholders into the proposal.

Feedback obtained from community members highlighted a general interest in the potential benefits associated with geotourism and geo-educational activities, alongside concerns regarding possible restrictions on land use following protected area designation [10].

In accordance with Article 12 [4], stakeholder engagement and public consultation will continue throughout the formal designation process, ensuring that landowners, local authorities, and other interested parties are adequately informed and involved in the establishment and future management of the proposed protected area.



Fig. 7. Identifying landowners in the Glameia area, from the property map (<https://geoportal.ancpi.ro>)(left) and local from Bosorod Village, presenting information about „Baia Glămeii” Cave (right).

The proposal will be prepared and submitted to the Bosorod Local Council and the National Agency of Environment and Protected Areas [13].

Following the submission of the scientific documentation, the designation of the Glămeia Scarp as a natural protected area of local interest follows a structured administrative process in accordance with Emergency Ordinance no. 57/2007 [4]. This process includes the technical evaluation of the proposal by competent environmental authorities, accompanied by expert review to verify the scientific validity and legal compliance of the documentation.

Subsequently, public consultations and hearings are organized to ensure transparency and to allow landowners, residents, and other relevant stakeholders to express their views. Upon completion of the consultation phase, the proposal is submitted for deliberation and voting by the Boșorod Local Council. If approved, the protected area status is formally established through a Local Council decision, which is published in accordance with legal requirements.

The final stages involve the official registration of the protected area within cadastral records and spatial planning instruments, ensuring its integration into national, zonal, and local land-use planning frameworks. In parallel, a local administrator is appointed by the local public administration authority to oversee the implementation of management measures, monitoring activities, and compliance with the established protection regime.

Discutions

The results of the present study demonstrate that the Glămeia Scarp fulfills the scientific, geomorphological, and educational criteria required for designation as a natural protected area of local interest under the provisions of Emergency Ordinance [4]. Its well-preserved morphostructural features, clear expression of cuesta-related landforms, presence of fossiliferous Middle Miocene deposits, and active geomorphological processes confer scientific value and justify formal conservation measures.

The case study highlights the effectiveness of a stepwise approach to geoconservation at the local administrative level. By combining scientific assessment, stakeholder engagement, and legislative procedures, local public authorities in Romania can successfully initiate and implement protected area designation.

A critical factor influencing the success of geoconservation initiatives is the understanding and support of both decision-makers and the local community. Insufficient involvement of local stakeholders may undermine conservation efforts, even when strong scientific arguments exist. Active engagement, transparent communication, and the integration of local knowledge are therefore essential to foster acceptance and long-term stewardship of geodiversity. In the case of Bosorod Commune, increased awareness of the escarpment's geological significance could facilitate its official recognition as a protected natural area through a Local Council decision.

Sustainable management of the Glămeia Scarp requires balancing conservation objectives with local socio-economic needs. Traditional land-use practices can coexist with protection measures, if management regulations are clearly defined and locally adapted. The site offers significant opportunities for geoeducation and geotourism, which could generate economic benefits for the Bosorod community while enhancing public understanding of geological heritage. The development of marked trails, interpretive panels, informational brochures, guided tours, and digital platforms dedicated to the escarpment's geological features would support these objectives.

According to national legislation, the responsibility for administering the proposed protected area would rest with the local public administration authority of Bosorod Commune. Management should be carried out by an appointed administrator operating under a management contract, ensuring the implementation of conservation measures, visitor regulation, and continuous monitoring of geomorphological processes. Such a governance framework would contribute to the long-term protection of the Glămeia Scarp while enabling its integration into sustainable local development strategies.

Overall, the Glămeia Scarp case study underscores the importance of local scale geoconservation initiatives as effective tools for preserving Romania's geodiversity. When supported by scientific evidence, community involvement, and coherent administrative action, local protected areas can play a crucial role in safeguarding geomorphological heritage and promoting sustainable territorial development.

Conclusions

This study outlines the steps required to protect Glămeia Scarp under Romanian legislation. The scientific evaluation confirms that the site holds significant geological and geomorphological value. Through proper local engagement and legislative procedures, Glămeia Scarp can be successfully declared a protected natural area of local interest.

Implementing geoconservation measures will ensure the long-term preservation of the site while supporting local sustainable development through education and geotourism.

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PROMOTING GEOSITES THROUGH TOURIST INFORMATION PANELS IN THE SCAUNUL ROTUND NATURAL RESERVE, BORSEC

Student Márkos György Mihai, Lecturer Radu NEGRU Ph.D.

*“Dimitrie Cantemir” University of Târgu Mureş, Faculty of Geography, Romania
Corresponding - Radu Negru: negrurg@yahoo.com*

Abstract

The “Scaunul Rotund” Natural Reserve in Borsec, situated in the Eastern Carpathians of Romania, is a remarkable geological and geomorphological area with significant potential for geotourism development. This paper evaluates the geological, geomorphological, and hydrological characteristics of the reserve, with particular emphasis on travertine deposits, karstic formations, caves, and mineral springs. The methodology combines bibliographic analysis, cartographic interpretation, and fieldwork to assess the natural features of the site and their role in supporting tourism. Special attention is given to the creation of tourist information panels as a tool for promoting geosites, raising visitor awareness, and encouraging sustainable tourism. The study concludes that enhancing interpretive infrastructure will contribute both to the conservation of the reserve’s natural values and to its attractiveness as a destination for geotourism, ecotourism, and educational tourism.

Keywords: promotion, geosites, panels, Scaunul Rotund, Borsec

Introduction

The promotion of natural heritage is an essential component of sustainable tourism. In geologically rich environments such as the Scaunul Rotund Natural Reserve, the interpretation of geological, geomorphological, and hydrological features can significantly improve tourist experiences and awareness. This paper addresses the role of tourist information panels in highlighting the unique natural values of the reserve.

The main objectives of this study are:

- To evaluate the geological, geomorphological, and hydrological elements of the “Scaunul Rotund” Reserve.
- To document and photograph the main geosites through fieldwork.
- To correlate field observations with existing cartographic and bibliographic data.
- To propose the design and implementation of informational panels at key geosites.

The “Scaunul Rotund” protected area is in the Borsec Depression, within the administrative territory of Borsec City (Fig. 1), in Harghita County.

This geological and botanical natural reserve (Code 2749) is a mixed reserve, IUCN Category IV, with an area of 40 ha, included in the Natura 2000 site ROSCI0252 Toplița – Scaunul Rotund Borsec (Fig. 2). It was established by Law No. 5/2000 on the approval of the National Spatial Planning Plan – Section III, Protected Areas [3].

The limits of the Scaunul Rotund Natural Reserve (Google Earth Pro)



Figure 1 shows the spatial boundaries of the Scaunul Rotund Natural Reserve as outlined on high-resolution Google Earth Pro imagery. The protected area is clearly marked by a polygon, separating it from nearby urban areas, agricultural land, and surrounding forests. The reserve lies close to the town of Borsec, with forested zones dominating its eastern part, highlighting the need for clear boundary delineation to support effective conservation and management.

Fig. 1. The limits of the Scaunul Rotund Natural Reserve (Google Earth Pro)



Figure 2 illustrates the spatial extent of the Natura 2000 site ROSCI0252 Toplița – Scaunul Rotund Borsec, outlined in red on a satellite base map. The figure shows the protected area's boundaries in relation to the surrounding landscape, highlighting its large, continuous forested coverage and the inclusion of multiple geomorphological units.

The map emphasizes the regional context of the site and supports the understanding of its conservation importance within the Natura 2000 network.

Fig. 2. Natura 2000 site ROSCI0252 Toplița – Scaunul Rotund Borsec [www.romaqua-group.ro].

Methodology

The research combines theoretical and empirical approaches. The main stages were:

- *Literature and cartographic review* -analysis of geological and topographic maps, satellite images (Google Earth Pro), and specialized studies on the geology, geomorphology, and hydrology of Borsec Depression.
- *Fieldwork* -identification, description, and photographic documentation of geosites; mapping of travertine outcrops, karst formations, and mineral springs.
- *Proposal for information panels* -designing interpretive tools to communicate geological and hydrological knowledge to tourists.

Geological, Geomorphological and Hydrological Features

The “Scaunul Rotund” Natural Reserve includes cliffs, caves, a travertine quarry, mofettes, and mineral springs.

The reserve is dominated by travertine formations, representing the most extensive deposit of its kind in Romania (approximately 40 hectares) [1]. The travertine originated from calcium-rich thermal waters during the Quaternary (Fig.3) and was later shaped by karstic processes [2].

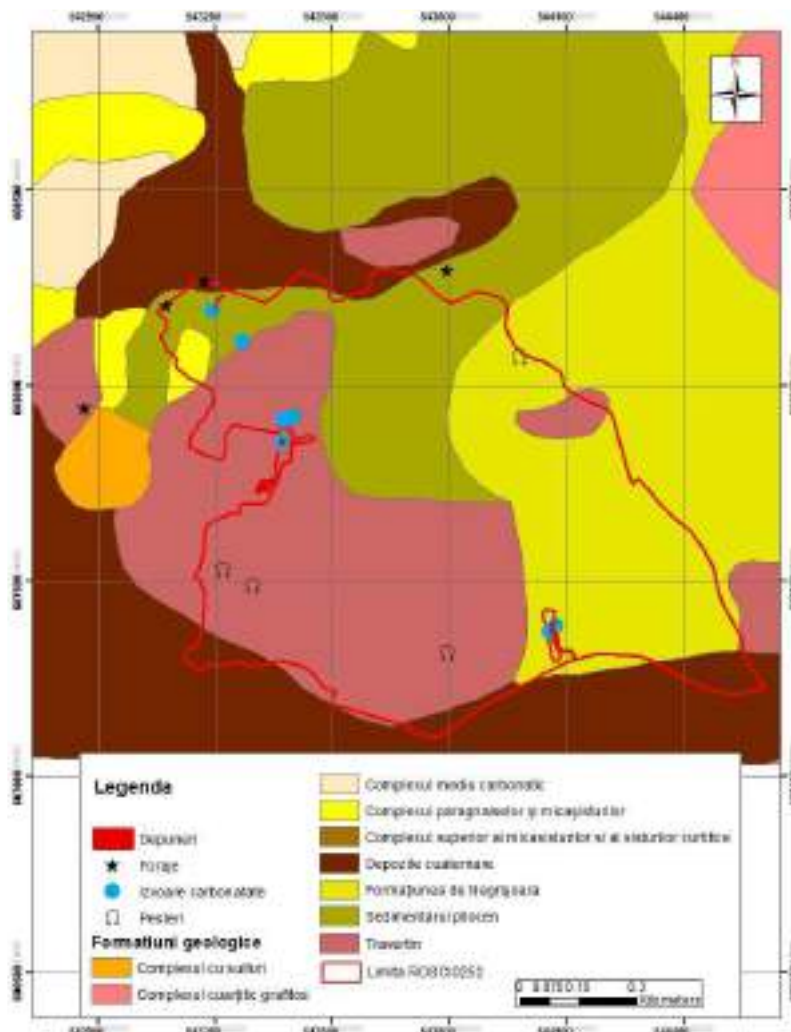


Figure 3 presents the geological framework of the Scaunul Rotund area within the Natura 2000 site ROSCI0252. The map shows the spatial distribution of major geological formations, including travertine deposits, Quaternary sediments, carbonate formations, and volcanic units, highlighted by different colors. The red outline marks the boundary of the protected area, while symbols indicate features such as springs, caves, faults, and carbonate deposits. Overall, the figure emphasizes the geological diversity of the site and the close relationship between lithology, structural elements, and the development of karst and mineral water features.

Fig. 3. Geological map [4].



Fig. 4. Scaunul Rotund Reserve: (a) Cetatea Bufnițelor; (b) Grotă Urșilor

(a) Geological and Geomorphological Elements of Cetatea Bufnițelor

Cetatea Bufnițelor is a sandstone formation located within the Scaunul Rotund Natural Reserve, offering a panoramic view of the surrounding area. The landform is shaped by limestone and travertine rocks and is the result of specific geomorphological processes characteristic of karst relief.

From a geological perspective, the area is composed of sedimentary rocks, where dissolution and erosion processes have led to abrupt formations and characteristic karst collapse features. Access to the site is restricted for safety reasons due to rock instability.

The panel includes photographs of the site, geological and geomorphological maps, a summary table of lithological and structural characteristics, and a QR code providing additional digital information.

(b) Geological and Geomorphological Elements of Grotă Urșilor

Grotă Urșilor is a natural formation resulting from the fracturing of Borsec travertine, subsequently enlarged by dissolution and erosion processes. The cave became accessible following natural rock collapse.

The name derives from the presumed use of the cave by bears as a shelter in the past. From a geomorphological standpoint, Grotă Urșilor illustrates an incipient karst system, where travertine dissolution is strongly influenced by water infiltration and carbon dioxide. The panel presents images of the cave interior, geological maps, a descriptive table outlining lithology, geomorphological processes, and sedimentary deposits (Quaternary–Holocene), as well as a QR code linking to supplementary content.



Figure 4.c. and d. Scaunul Rotund Reserve: (c) Ice Cave (Peștera de Gheață); (d) Travertine Quarry.

(c) Geological and Geomorphological Elements of the Ice Cave (Peștera de Gheață)

The Ice Cave developed within a massive travertine deposit formed by the precipitation of calcium carbonate from mineral spring waters. Subsequent tectonic fracturing allowed the formation of a cave system. The main gallery extends for approximately 40 m and includes ice formations, collapsed blocks, and galleries shaped by dissolution and gravitational processes. The cave is characterized by a stable microclimate, maintaining temperatures below 4°C throughout the year, which enables the preservation of ice deposits. This microclimate is influenced by cave orientation, air circulation, and the hydrothermal characteristics of the mineral waters. Ice accumulation occurs through infiltration water and freezing processes, including icicles and seasonal ice floors. Due to its fragile environment, tourist access is limited, and the cave represents an important geomorphological and microclimatic feature of the reserve.

(d) Geological and Geomorphological Elements of the Travertine Quarry

Travertine is a porous sedimentary rock formed by the precipitation of calcium carbonate from carbonated waters. The travertine quarry represents one of the historically important exploitation sites in Romania, with extraction activities beginning in 1819. The rock was widely used as an ornamental building material. Due to the need to protect the travertine deposits and surrounding groundwater resources, exploitation was progressively reduced and eventually ceased in 2004. At present, the former quarry is partially reclaimed by natural vegetation. The area is now accessible via marked trails, allowing visitors to observe exposed travertine

stratification and better understand the geological processes responsible for landscape formation.



Fig. 4.e and .f. Scaunul Rotund Reserve

(e) Geological and Geomorphological Elements of Poiana Zânelor

Poiana Zânelor is well known for its cold, carbonated mineral waters, traditionally used for therapeutic purposes, particularly for vascular conditions due to their circulation-stimulating effects. The area includes basins supplied with mineral water, historically used for bathing and drinking cures. From a hydrogeological perspective, Poiana Zânelor is located in a zone rich in bicarbonate–calcium and magnesium mineral springs. The footbath facilities arranged in the area contribute to balneary tourism, offering visitors an authentic traditional experience. The site also functions as a space for relaxation and meditation, valued for its tranquillity and natural landscape. The panel presents geological and geomorphological data related to travertine formations, karst processes, and Quaternary deposits, supported by maps, tables, and QR-linked digital content.

(f) Geological and Geomorphological Elements of the Pierre Curie Spring

The Pierre Curie Spring was discovered in 1932 by the French scientist Pierre Curie and is distinguished by its radium content, which has historically been associated with medical applications. The spring emerges from travertine formations and has been used for therapeutic purposes since the 1930s. Mineral waters from the spring are traditionally indicated for digestive and endocrine conditions. Geologically, the spring belongs to a deep hydrogeological system, where mineralized waters dissolve carbonate rocks and rise to the surface through

natural fractures. The interpretative panel includes site photographs, geological maps, a summary of lithological and hydrogeological characteristics, and a QR code providing access to supplementary educational materials.

The Borsec area is renowned for its mineral springs, which belong to the category of bicarbonated, calcic, magnesian, carbogaseous, and sulfurous waters. Within the reserve, notable springs include Pierre Curie, Izvorul 10 Kossuth, and Izvorul 11 Petofi. Hydrogeological processes are closely linked to tectonic dislocations, which created fissures facilitating the circulation and accumulation of mineral waters.

The main geosites identified in the reserve are:

- Cetatea Bufnițelor (Owls' Fortress) – a natural travertine and limestone cliff resembling a fortress.
- Grota Urșilor (Bears' Grotto) – a collapsed karstic microcanyon.
- Ice Cave – a cryogenic cave with perennial ice.
- Travertine Quarry – a site of historical exploitation, now serving as an educational location.
- Pierre Curie Spring – a mineral spring with elevated radioactivity.
- Fairies' Glade (Poiana Zânelor) – traditional therapeutic baths using cold mineral waters.

These geosites illustrate processes of travertine deposition, karstification and hydrogeological mineralization, offering exceptional opportunities for geotourism and geo-education.

Tourist Information Panels

Tourist information panels (Fig. 4) are essential tools for interpreting natural heritage. In the Scaunul Rotund Reserve, such panels can serve multiple purposes:

- Educational – explaining geological processes (e.g., travertine formation, karstification).
- Conservation-oriented – raising awareness of the fragility of karstic and hydrogeological systems.
- Touristic – enhancing visitor experiences by providing orientation, historical context, and visual aids.

Proposed locations for panels include the main geosites, entry points to the reserve, and along existing trails. Panels should integrate text, maps, photographs, and diagrams, using accessible language.

Conclusion

The “Scaunul Rotund” Natural Reserve represents one of Romania’s most valuable geosites due to its travertine formations, karstic caves, and mineral springs. Its promotion through tourist information panels will enhance public understanding of geological heritage while fostering sustainable tourism practices. Properly designed and strategically placed panels will serve as mediators between science and the public, ensuring that conservation and tourism development are balanced.

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PART V. ECONOMIC SCIENCES SECTION

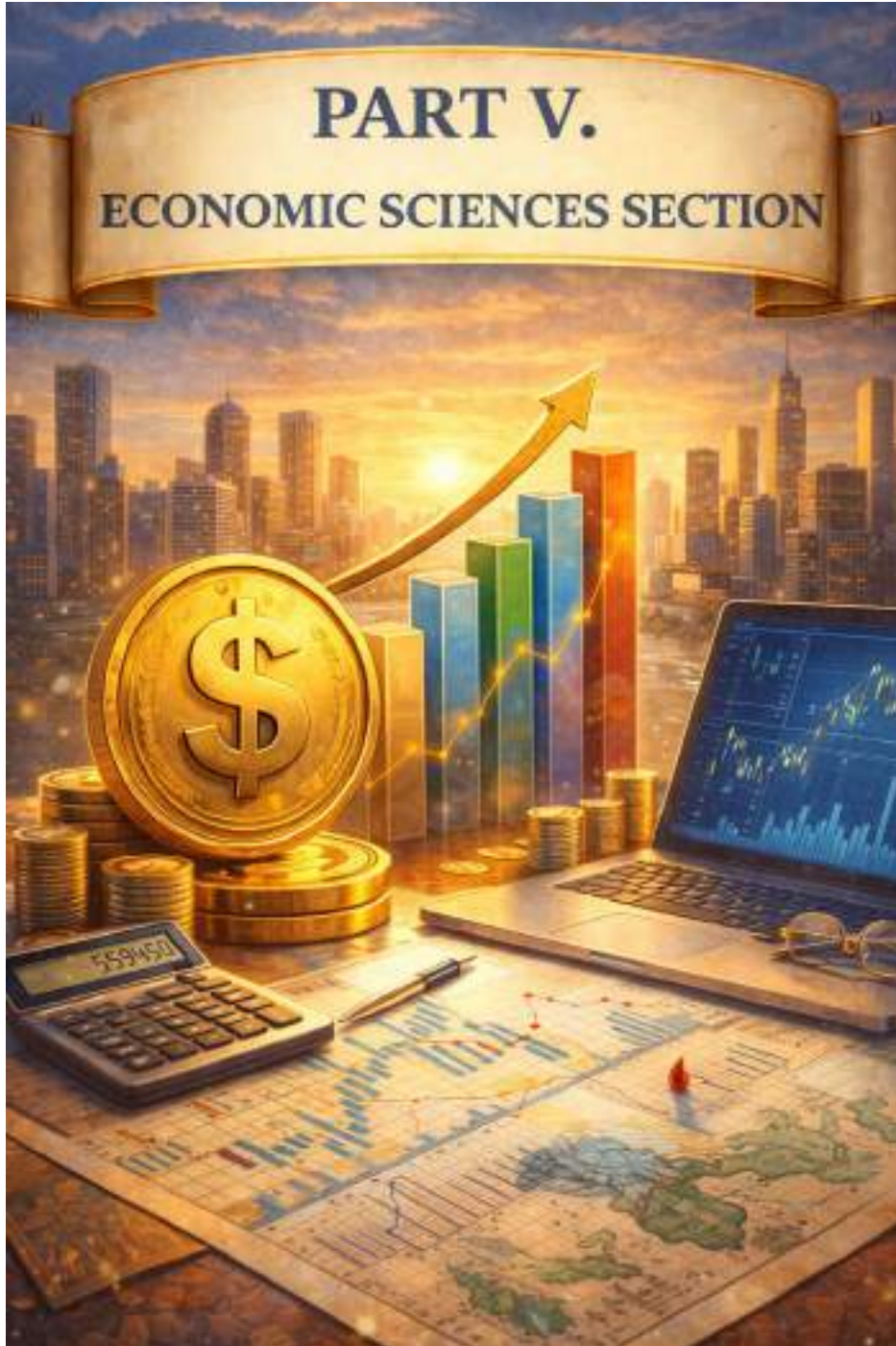


Figure P5. Economic Sciences Section — Markets, Growth, and Data-Driven Decision-Making

This illustrative plate was created collaboratively by S.M. Bălan and an AI-assisted design system to represent economic systems, financial analysis, and the role of quantitative modelling in contemporary economic research.

EDUCATING THE INTELLIGENT ECONOMY: INNOVATION THROUGH ARTIFICIAL INTELLIGENCE AND SUSTAINABILITY IN BUSINESS LEARNING

Bitila ZHULI, Ph.D.

"Eqrem Çabej" University, Faculty of Economy, Department of Public Administration, Gjirokaster, Albania
Corresponding author: Bitila Zhuli: bzhuli@uoqj.edu.al

Abstract

This study examines how the outcomes of the initiative “Promoting Sustainable Resource Management Practices in the Hospitality Sector in Gjirokastër” can inform innovative approaches to business and economics education. It explores how Artificial Intelligence (AI) can foster sustainability-oriented learning and reinforce collaboration between universities, students, and local enterprises—key drivers in building an intelligent, future-ready economy. The research aims to (1) evaluate the feasibility of integrating AI-based sustainability concepts across business curricula, and (2) analyze perceptions of their relevance, effectiveness, and potential impact on future professional practice. A mixed-methods approach was adopted, combining curriculum analysis, structured questionnaires with students and educators, and interviews with business representatives to assess both readiness and perceived value. Although AI tools such as predictive analytics, virtual sustainability labs, and digital monitoring platforms are not yet part of existing programs, respondents identified them as essential for enhancing learning quality, analytical competence, and sustainable decision-making. Importantly, these tools can be implemented using the university’s existing infrastructure — including computer labs, digital libraries, internet access, and open-source educational platforms — making integration both practical and cost-effective. Findings suggest that integrating AI-supported sustainability modules into business education strengthens innovation capacity, critical thinking, and student engagement. This approach offers a replicable model for aligning higher education with the evolving demands of the digital and green economy, positioning innovation as the bridge between knowledge, technology, and sustainable growth.

Keywords: Artificial Intelligence, Innovation in Education, Sustainable Business, Curriculum Integration, Intelligent Economy.

Introduction

The global economy is increasingly shaped by digital innovation and environmental imperatives, calling for a new educational paradigm that integrates these dimensions. In a world characterized by diverse cultures, demographics, and political ideologies, progress toward sustainable development requires an expanded use of digital technologies [1]. Within the educational sphere, these transformations underscore the urgency of curriculum reform, particularly in higher education programs in economics and management. Contemporary business education is now expected to embed environmental, social, and ethical aspects of sustainability alongside digital competencies [2]. This need is especially evident in regions

where sectors such as tourism, hospitality, and local enterprises hold significant economic importance.

Simultaneously, rapid technological advancements—especially in Artificial Intelligence (AI) — have created new opportunities for improved analysis, planning, and data-driven decision-making. These developments align with recent literature suggesting that AI can enhance sustainability-oriented learning and strengthen the quality of managerial decisions. Consequently, the concept of sustainability is becoming increasingly interlinked with digital transformation (DT [3].

Against this backdrop, the present study investigates the role of Artificial Intelligence in catalyzing innovation within business education, with a particular focus on sustainability in resource-intensive and locally relevant sectors such as hospitality. The research examines how AI-enabled learning can better prepare students and future professionals for the requirements of a smart economy shaped by the dual pressures of technological change and sustainability. Furthermore, it aims to assess the perceptions and readiness of students, educators, and business representatives to adopt and benefit from such an integrated, sustainability- and technology-oriented educational approach.

Background and Rationale

Business and economics education have traditionally focused on efficiency, profitability, and market dynamics without sufficient integration of sustainability principles or advanced technologies like AI. However, sustainability is increasingly becoming a core driver of business strategy worldwide. Concurrently, AI offers transformative opportunities in data analysis, decision support, and personalized learning, which can enhance education outcomes.

Research Objectives

This study is designed to achieve two primary objectives.

First, it aims to evaluate the feasibility and practical implications of integrating AI-driven sustainability tools and learning modules into business and economics curricula. This includes examining the extent to which existing institutional infrastructure, pedagogical practices, and curriculum structures can support the adoption of AI-enabled instructional approaches such as virtual sustainability labs, predictive analytics platforms, and simulation-based learning environments. Second, the research seeks to analyze the perceptions, expectations, and readiness of key stakeholders — including students, academic staff, and representatives from local enterprises — regarding the relevance, usefulness, and potential impact of these AI-supported innovations. This objective focuses on understanding how different groups view the role of AI in enhancing sustainability competencies, improving professional preparedness, and strengthening the alignment between higher education and evolving labor-market demands.

By addressing these objectives, the study aims to provide evidence-based insights that can guide curriculum development, foster stronger university–industry collaboration, and inform broader educational reforms aimed at preparing graduates for an increasingly digital and sustainability-oriented economy.

Literature Review

AI in Education

Recent research shows that Artificial Intelligence (AI) is reshaping business education by enhancing analytical skills, personalizing learning pathways, and enabling data-driven decision-making. Das (2025) highlights that AI-driven systems—such as recommendation engines, automated feedback tools and predictive analytics—support more interactive and competency-oriented learning environments in business schools [4]. Similarly, Dias and Laurretta (2024) emphasize the expanding role of deep learning across business functions, noting that AI-based analytical and operational tools are increasingly integrated into management curricula to reflect real-world complexity [5].

In higher education, AI is also considered a strategic component for advancing sustainable and adaptive learning models. Bagherimajd and Khajedad propose a comprehensive model of sustainable education grounded in AI-enabled instructional design, suggesting that intelligent systems can optimize learning processes, strengthen engagement, and support continuous skills development across various academic disciplines [6].

Sustainability Education in Business

Embedding sustainability in business programs has become a defining priority for modern higher education. Cocu et al. argue that the shift toward sustainability-oriented business education encourages systems thinking and responsible managerial behavior, strengthening students' capacity to understand the interconnected economic, social, and environmental dimensions of decision-making [2]. Serafimova notes that the digital age intensifies these demands, as organizations increasingly rely on data, technology, and sustainability frameworks to navigate global transitions [7].

Synergies between AI and Sustainability Education

Growing literature explores the emerging intersection of AI and sustainability education within business schools. Leal Filho et al. demonstrate that AI can enrich sustainability-oriented learning by enabling simulations, environmental impact modelling, and data-driven scenario analysis [8]. Their findings suggest that combining AI tools with sustainability content elevates students' capacity to evaluate resource efficiency, forecast ecological outcomes, and integrate sustainability principles into managerial strategies.

In the hospitality sector, Bekele et al. show that digital transformation contributes to improved environmental performance [9]. Their longitudinal study evidence that AI-enabled technologies and data analytics can enhance resource management practices, thereby reinforcing the rationale for integrating AI-based sustainability teaching in business and tourism education.

Kusetogullari et al. further support the potential of AI—particularly generative AI—to transform entrepreneurship education by offering advanced tools for experimentation, ideation, and innovation [10]. These capabilities align naturally with sustainability-focused curricula, providing opportunities for learners to develop solutions that combine technological intelligence with environmental responsibility.

Finally, Camodeca and Almici emphasize that digital transformation aligns closely with the sustainability priorities outlined in the UN 2030 Agenda [3]. Their findings reinforce the idea

that preparing students for an intelligent, sustainable economy requires curricula that integrate technology, data literacy, and sustainability-driven management frameworks.

Research Methodology

A mixed-methods research design was adopted to obtain a comprehensive understanding of how AI and sustainability are integrated into business education and how these competencies align with the needs of the local hospitality sector. The study combined qualitative and quantitative techniques to ensure methodological triangulation and enhance the validity of findings.

First, a curriculum content analysis was conducted to systematically examine existing course materials, syllabi, and program structures in order to determine the extent to which AI-related themes, sustainability principles, and their intersections are currently embedded within business and hospitality curricula.

Second, structured questionnaires were administered to both students and academic staff. These instruments were designed to assess participants' level of preparedness, familiarity with AI-enabled learning, perceptions of sustainability competencies, and their perceived relevance to future employability and professional development.

Finally, semi-structured interviews were carried out with representatives from local hospitality enterprises. These interviews aimed to capture industry expectations, identify competency gaps, and explore opportunities for collaboration between higher education institutions and the hospitality sector in fostering an intelligent and sustainable workforce.

Participants

The study involved a diverse group of stakeholders representing higher education and the regional business community. A total of 321 students enrolled in business and economics programs across the Universities of Gjirokastrë, Vlorë, Sarandë, and Korçë participated in the survey component. Their inclusion provided a broad perspective on student readiness, exposure to AI-based learning tools, and attitudes toward sustainability-oriented competencies.

In addition, 35 educators with direct responsibilities in curriculum development, course delivery, and pedagogical planning contributed to the study. Their insights were essential for understanding current instructional practices, perceived curricular gaps, and institutional priorities related to AI and sustainability integration.

The qualitative component included 88 representatives from local enterprises operating in southern Albania, primarily within the hospitality and tourism sectors. These participants offered practitioner-level perspectives on industry needs, emerging skill demands, and opportunities for collaboration with academic institutions.

Material and Method

Data collection employed a structured, mixed-format questionnaire consisting of three types of items: general demographic and background questions; closed-ended items measuring perceptions and readiness toward AI and sustainability using a "five-point Likert scale" and open-ended questions designed to elicit more nuanced reflections and suggestions from respondents. This combination enabled the capture of both quantifiable patterns and richer, context-specific insights.

Quantitative data from the questionnaires were processed using descriptive and inferential statistical techniques to identify prevailing trends, levels of readiness, and variations across participant groups. Qualitative responses from the open-ended items were systematically coded and thematically analyzed to uncover emergent themes that complemented the statistical results.

Semi-structured interviews with business representatives were recorded and analyzed using thematic analysis. This approach enabled the identification of recurring themes related to industry expectations, competency gaps, and the potential contributions of higher education to workforce development in an intelligent and sustainable economy.

Furthermore, curriculum documents, including syllabi and program descriptions, were systematically reviewed and evaluated against established "AI and sustainability learning indicators". This document analysis facilitated a comparative assessment of the degree to which current academic programs reflect contemporary technological and environmental demands.

Results

Curriculum Findings

Existing universities programs did not include explicit modules on Artificial Intelligence or advanced practice-oriented sustainability concepts. Sustainability was primarily addressed at a theoretical or conceptual level, often limited to general discussions of environmental or ethical principles rather than practical application. Likewise, AI tools—such as predictive analytics, automated data processing, digital monitoring systems, or virtual simulation environments—were largely absent from teaching and learning activities. As a result, students were not exposed to hands-on experiences that demonstrate how AI can support sustainable resource management, strategic planning, or evidence-based decision-making in real business contexts. This gap highlights the need for curricular innovation that integrates both sustainability competencies and AI-enabled methodologies in a more systematic and applied manner.

Perceptions and Readiness

The findings indicate a strong and consistent consensus among participants regarding the relevance and necessity of integrating AI-supported sustainability learning into higher education. More than 82% of students and educators emphasized that the inclusion of Artificial Intelligence tools within sustainability-oriented curricula is essential for improving the quality of teaching, strengthening analytical capacities, and preparing graduates for the evolving demands of the labor market. Respondents highlighted that AI-based tools—such as predictive analytics systems, virtual sustainability laboratories, and digital monitoring platforms—hold significant potential to enhance students' abilities to interpret complex datasets, model scenarios, and make informed decisions grounded in evidence. Furthermore, 69% of local business representatives expressed a high degree of openness and willingness to collaborate with the university in jointly developing practical learning experiences that link AI applications to sustainable resource management practices. Such partnerships were perceived as mutually beneficial, enabling businesses to contribute to the development of a more skilled workforce, while providing students with opportunities to apply theoretical knowledge in real operational environments. This willingness for cross- sectoral collaboration underscores the value of integrating AI-driven experiential learning into business education.

Availability of Infrastructure

The institutional assessment also revealed that the universities already possess the foundational infrastructure required to support the integration of AI-focused modules at relatively low additional cost. Existing resources—including computer laboratories equipped with sufficient hardware, stable internet connectivity, access to digital libraries and academic databases, and various open-source educational platforms—provide a strong baseline for implementing AI-enabled teaching approaches. This infrastructural readiness suggests that significant innovations in curriculum design can be achieved without the need for major financial investment, thereby increasing the feasibility and sustainability of proposed curricular reforms.

Conclusion

Integrating AI-supported sustainability modules into business and economics education represents a strategic and forward-looking approach to preparing students for professional roles within an increasingly intelligent and technology-driven economy. Such integration not only enhances students' digital literacy but also strengthens their ability to think critically about complex sustainability challenges. By combining technological competence with sustainability awareness, this pedagogical model encourages innovation, systems thinking, and more effective collaboration between academia and industry stakeholders.

The findings of this study demonstrate strong support among students, educators, and local business representatives for embedding AI-based sustainability education within business curricula. This alignment reflects a growing recognition of two urgent priorities in contemporary business education: first, the necessity of equipping future professionals with the digital skills and analytical capacities required by the intelligent economy; and second, the importance of fostering sustainability mindsets that are essential for driving responsible business innovation and long-term value creation. Stakeholders consistently emphasized that AI tools — such as predictive analytics, simulation models, and digital monitoring platforms — can significantly enhance students' ability to interpret data, identify trends, and make evidence-based decisions.

Practical implementation appears highly feasible, given that universities can leverage existing institutional infrastructure to introduce virtual sustainability laboratories, AI-driven data-analytics projects, and interactive simulation platforms tailored to local economic sectors, including sustainable hospitality management. Embedding such experiential learning opportunities within the curriculum can substantially enhance student engagement, problem-solving skills, and real-world readiness. These findings are consistent with global trends advocating for comprehensive education reform to address the interconnected challenges posed by technological advancement, environmental pressures, and evolving labor-market expectations.

The integration of AI into education and business cannot be done with enthusiasm alone, but requires critical reflection, ethics, transparency, and attention to medium- and long-term impacts.

Recommendations

Redesign curricula to incorporate AI and sustainability content in a structured and coherent manner.

Higher education institutions should undertake systematic curriculum reform to ensure that AI-driven analytical tools, sustainability frameworks, and interdisciplinary applications are integrated across business and economics programs. This includes embedding modules on data analytics, predictive modelling, digital sustainability assessment, and simulation-based learning within existing course structures. Curriculum redesign must also emphasize pedagogical coherence, ensuring that learning outcomes, teaching materials, and assessment methods reflect current industry demands and prepare students for a data-intensive and sustainability-oriented professional environment.

Invest in continuing professional development to increase faculty capacity in AI-enabled teaching.

Faculty readiness is essential for effective curriculum innovation. Universities should provide continuous professional development programs that equip educators with practical competencies in AI tools, digital pedagogy, and sustainability modelling. Training initiatives may include workshops, online certification modules, collaborative learning groups, and industry-led seminars. Strengthening faculty expertise will not only improve teaching quality but also foster a culture of innovation where educators actively integrate intelligent systems and sustainability concepts into their instructional practices.

Expand collaborations with local businesses to support applied and experiential learning.

Deepening partnerships between universities and local enterprises — especially in sectors such as hospitality, tourism, and services — can significantly enhance the relevance and impact of business education. Co-created projects, internships, field studies, and joint research initiatives enable students to apply AI-enabled sustainability tools within real operational settings. Such collaborations also help align academic programs with evolving labor-market expectations, allowing employers to contribute directly to shaping a workforce equipped with digital, analytical, and sustainability competencies. Strengthening these university–industry linkages ensures that learning is both experiential and contextually grounded.

Implement ongoing monitoring and evaluation systems to assess student skill development and workforce readiness.

Continuous assessment mechanisms are necessary to evaluate the effectiveness of newly introduced AI- and sustainability-focused modules. Universities should develop monitoring frameworks that track student progress in digital literacy, analytical reasoning, and sustainability problem-solving. These systems may include competency-based evaluations, digital portfolios, performance analytics, and feedback loops involving employers and alumni. Such monitoring enables institutions to make data-driven adjustments to curricula, improve instructional quality, and ensure that graduates possess the skills required to contribute effectively to an intelligent and sustainable economy. Additionally, longitudinal tracking of graduate outcomes can help assess whether the educational reforms translate into increased employability and stronger regional economic impact.

Limitations and Future Research

This study is limited by its focus on a single regional initiative and a specific stakeholder group, which may limit the generalizability of its findings.

Future research would benefit from longitudinal studies examining the lasting impact of AI-supported sustainability education, cross-institutional comparisons, and deeper investigations into which AI tools most effectively improve learning outcomes across business disciplines.

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AI-BASED ASSESSMENT INFRASTRUCTURE FOR MODERN UNIVERSITIES: A PILOT MODEL FOR KARABAKH UNIVERSITY

Candidate Seyidmahir ZAKIZADE Ph.D.

Baku Business University, Business Organization and Municipal Management, Azerbaijan

Corresponding author - Seyidmahir Zakizade: seyidmahir.1996@gmail.com , <https://orcid.org/0000-0002-5218-9453>

Abstract

The study examines the possibilities of applying artificial intelligence in the assessment processes of educational institutions and proposes implementing this approach as a pilot project at Karabakh University. AI-based assessment systems analyze students' responses, automate the grading of assignments, and ensure the objectivity of results. This technology more accurately identifies students' knowledge levels, detects learning gaps, and highlights the areas where instructors need to intervene. The pilot implementation not only shortens the assessment period but also reduces instructors' workload, thereby increasing the overall efficiency of the process. The model planned for Karabakh University can play a significant role as an innovative approach aimed at improving teaching quality, strengthening digital governance, and establishing transparent assessment mechanisms.

Keywords: Artificial Intelligence (AI), AI-based Assessment, Higher Education Evaluation, Learning Analytics, Automated Essay Scoring, Digital Governance in Education, Karabakh University, Educational Technology.

Introduction

The use of artificial intelligence in the education system-particularly in assessment-has become one of the most widely discussed directions in contemporary international academic literature. Holmes and Papamitsiou note that AI-based analytic systems can process student performance data and produce more accurate and objective assessment outcomes [1]. This minimizes the degree of teacher subjectivity and increases the reliability of results. Such an approach is especially important for educational institutions because assessment has a direct impact on both teaching quality and students' learning motivation.

Other studies show that artificial intelligence performs functions such as semantic analysis of student responses, the application of language models, and automatic categorization of errors, operating more rapidly and continuously than traditional assessment methods. In this regard, Liu and Xu emphasize that AI-based automated assessment systems demonstrate high accuracy even in short-answer and essay-type tasks, and they better identify the depth of students' knowledge [2]. The authors further argue that this approach significantly reduces teachers' grading workload, allowing them to allocate more time to purposeful pedagogical activities.

Comparative studies indicate that the impact of artificial intelligence on assessment processes varies across different educational environments. In student-centered and personalized learning systems, AI is characterized mainly by predictive analytics and adaptive

assessment functions, whereas in large-scale higher education settings its primary advantages relate to speed and objectivity. Chen and He [3] explain that systems working with small groups employ AI's adaptive learning capabilities more effectively, while automation functions yield higher efficiency in large universities. This comparison shows that AI can adapt to various educational models and can enhance the quality of assessment results regardless of the structure of the assessment system.

Recent research on the influence of artificial intelligence on educational assessment mechanisms shows that generative and deep learning models can further enhance assessment quality. For example, Misgna [4] states that deep learning-based automated essay scoring systems can evaluate not only the content of the response but also its argumentation structure, coherence, and language fluency. This approach makes it possible to measure students' higher-order thinking skills and provides more consistent results than traditional evaluation. As the author notes, since AI models are not affected by emotional or fatigue-related factors, they possess a particular advantage in ensuring consistency and neutrality in assessment.

Moreover, recent studies demonstrate that AI-based analytics not only evaluate outcomes but also model the learning process itself at a deeper level. Rodríguez-Ortiz and colleagues [5] show that learning analytics powered by generative AI is highly effective in predicting students' performance patterns, identifying risk groups, and proposing individualized learning strategies. Their study reveals that AI extends beyond assessment to become a broader mechanism of pedagogical management. Such models enable higher education institutions to manage the teaching process more purposefully and facilitate real-time monitoring of student performance.

At the same time, the bibliometric analysis conducted by Bedizel [6] reveals that the use of artificial intelligence in assessment has become a rapidly growing trend in the scientific literature in recent years. The study shows that between 2020 and 2023, the number of publications on AI and assessment more than doubled, with the main research directions focusing on automated response analysis, adaptive assessment, and the application of generative models. The author notes that education systems have already begun to use AI actively not only for outcome-based assessment but also for process-oriented evaluation. This shift strengthens both transparency and learner-centered approaches in higher education.

These scientific findings confirm that artificial intelligence possesses significant potential for improving assessment practices in higher education systems. The pilot project planned at Karabakh University creates a new opportunity for the application of these global scientific trends within the local educational environment. Implementing an AI-based assessment model in this newly established academic setting will enhance transparency across evaluation processes, create a more accurate measurement mechanism, and facilitate continuous monitoring of students' developmental progress. The pilot initiative will also accelerate the university's transition to digital governance and contribute to the establishment of a modern assessment ecosystem aligned with international best practices.

Research Content

Global scientific findings indicate that the integration of artificial intelligence into assessment processes creates substantial advantages both technically and pedagogically. As a logical continuation of these research trends, the implementation of similar approaches within the Azerbaijani education system has become one of the pressing contemporary issues. In recent years, the expansion of digital management, electronic learning environments, and data-analytics-based monitoring mechanisms in higher education institutions has created favorable conditions for the adaptation of AI to assessment processes. In particular, increasing the

objectivity of assessment results, optimizing teachers' workload, and accurately tracking students' learning progress are considered key priorities of the national education strategy. Therefore, the implementation of AI-based assessment models-whose effectiveness has been confirmed in international practice-is both strategically necessary and pedagogically appropriate for Azerbaijan.

Karabakh University offers a uniquely advantageous environment for implementing such a pilot model due to its emerging academic infrastructure and flexible administrative framework. As a newly established institution, it is not constrained by legacy assessment systems or outdated procedural norms, allowing modern digital tools to be integrated from the outset. The university's strategic orientation toward digital governance, innovation-driven curriculum development, and data-based decision-making further strengthens its suitability as the primary testing ground for an AI-based assessment model. These institutional characteristics create an opportunity to design an evaluation system that is both technologically advanced and pedagogically aligned with contemporary international standards.

Within the Azerbaijani context, the most suitable environment for introducing this approach is Karabakh University. The newly established academic institutional structure and the emerging educational environment allow the university to transition directly to innovative AI systems without repeating the limitations of traditional assessment models. The AI-based assessment model envisaged as a pilot project at Karabakh University can ensure the automatic processing of student responses, the consistent and objective formation of assessment results, and real-time monitoring of the teaching process.

The findings of international research indicate that the successful integration of AI-based assessment models in higher education depends not only on the technical capabilities of the system but also on the structural characteristics of the local academic environment. In the context of Azerbaijan, Karabakh University presents particularly favorable conditions for piloting this model due to its newly established institutional structure, flexible digital management framework, and the absence of rigid traditional evaluation practices. Therefore, the core focus of this research is to assess the compatibility of AI-driven assessment mechanisms with local educational processes, identify potential risks and implementation requirements, and outline the stages through which a pilot AI-based evaluation model can be introduced in this emerging academic setting. This analytical approach strengthens both the theoretical and applied dimensions of the study and provides a solid foundation for adapting AI-based assessment tools to the institutional needs of Karabakh University.

Discussion

Scientific results obtained in international research make it possible to predict the potential impacts of this model planned for Karabakh University. The analytical advantages highlighted by Holmes and Papamitsiou [1] objective processing of student responses, systematic categorization of errors, and the maintenance of assessment consistency-suggest that the pilot model could generate similar outcomes in the local educational environment. This technological approach can contribute to organizing the assessment process at Karabakh University in a more accurate and transparent manner.

One of the key anticipated benefits discussed is the optimization of teachers' workload. Liu and Xu [2] demonstrate that AI-based automated assessment systems accelerate the grading of written responses, allowing instructors to allocate more time to pedagogical activities. The same principle can be applied to Karabakh University, potentially improving the quality of teaching

in a newly established higher education institution. Thus, the implementation of the pilot model carries significant potential in terms of reducing teachers' workload and enhancing the efficiency of resource use.

Another expected outcome is the improved precision with which students' learning trajectories can be monitored. Chen and He [3] show that AI-based analytics identify subtle aspects of students' knowledge levels and help detect learning gaps in a timely manner. For Karabakh University, this capability is particularly important for the personalization of the teaching process and the strengthening of student-centered monitoring mechanisms. In a newly developing academic environment, such a system may directly influence the quality of learning and align with the university's innovative educational strategy.

However, certain limitations must also be considered within the discussion. Since AI-based assessment systems require large volumes of data, the adaptation process at Karabakh University may initially be accompanied by specific challenges. An incomplete data infrastructure may temporarily affect the system's accuracy, which is why parallel supervision by academic staff will be necessary during the early phase. Nevertheless, these limitations are typical for all pilot projects and can be mitigated through proper technical support and a phased implementation strategy.

In addition to these anticipated benefits, comparative international experiences reveal several important considerations for implementing AI-based assessment models in newly established academic environments. Pilot initiatives in South Korea, Singapore, and Finland demonstrate that the early phases of AI-driven evaluation require strong data governance protocols, continuous calibration of automated scoring models, and close human–AI collaboration to prevent bias and misclassification. These examples indicate that while AI significantly improves assessment accuracy and efficiency, its effectiveness largely depends on the creation of reliable data streams and the contextual adaptation of algorithms. For Karabakh University, these insights suggest that the pilot model should be launched with a structured quality-assurance framework, ensuring that the system remains transparent, pedagogically valid, and aligned with the university's emerging digital ecosystem.

Findings and Recommendations

Theoretical and comparative analyses indicate that the implementation of artificial intelligence-based assessment systems in higher education environments has substantial potential. A review of the scientific literature shows that AI algorithms process student responses more accurately, consistently, and efficiently, reduce the influence of subjective factors, and enhance transparency in the assessment process. This technology surpasses traditional assessment methods by enabling semantic analysis of written tasks, identifying error patterns, and detecting knowledge gaps.

The research also reveals that adaptive assessment and continuous monitoring functions allow for a precise analysis of students' learning trajectories. Applying these technologies at Karabakh University could support real-time tracking of student performance, identification of individual learning needs, and the personalization of instruction. Initial evaluations suggest that this model aligns with the university's innovative structure and is unlikely to encounter serious institutional barriers in terms of practical implementation.

However, several potential limitations have also been identified. For AI systems to operate with high accuracy, the availability of a broad and high-quality data repository is essential, which may require a certain period of adaptation in a newly formed academic environment.

Moreover, ensuring that AI systems can fully evaluate student responses in the correct context necessitates the adaptation of algorithms to local curricular materials.

The analysis of the proposed implementation of an AI-based assessment model demonstrates that effective use of this system at Karabakh University requires preparatory measures at pedagogical, technical, and administrative levels. Although existing scientific studies confirm that integrating artificial intelligence into the assessment process creates real opportunities for improving quality in higher education, the success of implementation depends on fulfilling several preliminary conditions. Therefore, the following recommendations outline the key directions for the effective application of AI-based assessment systems at Karabakh University:

1. A phased implementation strategy should be developed. The pilot model should first be tested within a limited group of courses, and its accuracy indicators should be calibrated by running the system in parallel with instructor-based assessment.
2. A high-quality data repository should be established. For AI systems to operate effectively, a structured database of student responses, essay samples, and test results must be created.
3. Technology-focused training should be provided for instructors. Practical workshops and methodological training programs should be developed to ensure that academic staff are able to operate the system correctly.
4. The AI system should be integrated with the university's existing digital management platform. A unified platform will facilitate the monitoring of assessment results, preparation of analytical reports, and tracking of student performance.
5. A post-pilot expansion strategy should be designed. Based on the results obtained during the initial phase, the system should be expanded across faculties and transformed into a standard assessment mechanism at the university level.

Conclusion

Scientific analyses indicate that AI-based assessment systems possess substantial potential for optimizing measurement and monitoring processes in higher education. Findings from international research demonstrate that AI algorithms surpass traditional methods in terms of objectivity, accuracy, and speed, while simultaneously strengthening instructors' decision-making capabilities. These scientific foundations provide a solid theoretical basis for the implementation of the proposed pilot project at Karabakh University.

The newly emerging academic environment offers a favorable platform for integrating artificial intelligence and aligns with the university's digital transformation strategy. It is expected that, once the pilot model is implemented, the assessment mechanism will become more transparent, students' learning trajectories will be monitored in real time, and instructors' workload will be optimized.

At the same time, the successful application of the system requires strengthening the data infrastructure, organizing teacher training, and implementing a phased adaptation strategy. Consequently, the introduction of an AI-based assessment model at Karabakh University can make a significant contribution to the formation of a modern and innovative higher education environment in the region, enhance the quality of teaching, and increase the university's competitiveness.

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INNOVATION AND HUMAN RESOURCE MANAGEMENT, REALITIES AND CHALLENGES

Lecturer Daniela QIQI Ph.D.

"Eqrem Çabej" University of Gjirokaster, Faculty of Economy, Albania
Corresponding author: Daniela Qiqi: dqiqi@uogi.edu.al

Abstract

In the era of Artificial Intelligence (AI) and rapid technological development, the integration of AI technologies for carrying out various HRM functions such as recruitment/selection, training, performance evaluation, compensation and employee involvement in decision making has become a key factor in improving efficiency and gaining competitive advantage. This study assesses the use of technology in HRM issues in the region of Gjirokaster and addresses how AI may impact HRM strategies through process automation, facilitating data-based decision-making, and continuously improving the professional competencies of managers, without of course overlooking the ethical and organizational challenges that accompany them. Through a strategic management approach, the necessity of developing new technological skills and university-labor market cooperation is emphasized because the inclusion of AI in education is a strategic investment for the future that can only be realized through a comprehensive, ethical, and innovative education. In conclusion, the study suggests a balanced approach that combines human judgement with AI-based analysis aiming to increase productivity, promote HR best practices and strengthen development sustainability.

Keywords: Artificial Intelligence, Human Resources, Education, Strategic Management, Ethics.

Introduction

Nowadays, we are all living in an era where technological development is progressing at a rapid pace and innovation has become the focus of our daily lives. These changes certainly cannot fail to affect the way private companies or state institutions manage their work. The use of innovation enables companies or institutions to collect and analyze data in real time, predict development trends, reduce errors, and improve transparency in their internal processes. Also, technological development helps its users to be more flexible in making their decisions to respond as quickly as possible to market demands and its constant changes.

The use of technology and innovation certainly could not fail to extend to modern human resource management (HRM) processes and practices. The integration of intelligent systems into key HR management functions such as recruitment/selection, employee training, performance evaluation and reward management constitutes a competitive advantage because it improves organizational efficiency by reducing costs and increasing employee productivity.

This general trend of incorporating intelligent systems into management has certainly included Albania, which has made important steps in this direction in both the public and private sectors. But despite this reality, it is worth noting that there is a notable lack of genuine academic studies that address the relationship between innovation and management in general or HRM

in particular, both at the national and local levels. Therefore, this study, which was conducted in the Gjirokastra Region, aims to make its contribution in this direction. Another reason for conducting this study is the contribution that this study and its findings can make to improving the curricula offered at the University of Gjirokastra, because following labor market developments and adapting curricula according to its needs is an essential aspect for preparing future professionals who need to face the challenges of a digitalized economy and a work environment in which technology is increasingly used.

Methodology

In this study, the primary data collection method was initially used. To understand the real use of AI in HRM, based on the existing HRM literature and modern technological developments, a questionnaire was designed which included several questions regarding the level of use of traditional methods or intelligent systems in four main HRM practices: recruitment/selection, employee training, performance evaluation and reward management.

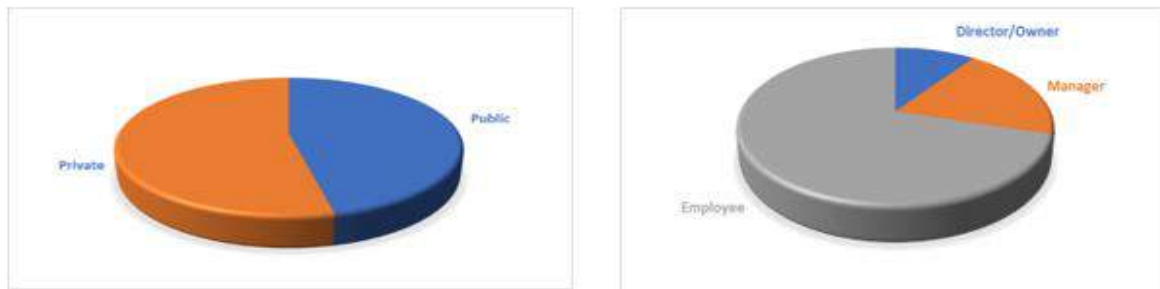
In order to identify current HRM practices and how and to what extent technology is used for recruitment/selection, training, performance evaluation and reward, questionnaires were distributed to be completed by directors/owners, managers and employees of both the public and private sectors.

Furthermore, based on secondary data from existing literature, regional reports and studies on the implementation of AI in HRM, a descriptive and empirical analysis was conducted to assess the use of technology in HRM in the Gjirokastra region. After these analyses, advantages and disadvantages of using technology in this direction were identified and some conclusions were drawn regarding the real situation.

The combination of primary and secondary methods enabled a comprehensive and balanced assessment of how technology can improve HRM in the local context of Gjirokastra. Also, by assessing the advantages and limitations of the use of intelligent systems, some applicable recommendations have been brought for all stakeholders, whether they belong to the public, private or educational sectors.

Results and data analyses

➤ For the purpose of this study, the questionnaire was distributed to various companies and institutions in the Gjirokastra Region, which belong to both the public and private sectors. 71 responses were collected, which are almost equal in number, specifically 54% come from the public sector and 46% from the private sector (Graph 1). According to the job position, the respondents belong to this typology: about 10% of them hold the position of Director/Owner, 20% the position of manager and about 70% are employed (Graph 2). The collection of opinions from these 3 groups was done with the aim of creating a complete panorama (360 degrees) on the concrete situation of the use of innovation in HRM issues.



Graph1. Do you work in the public or the private sector? **Graph 2.** What position do you hold?

➤ In this perspective, the respondents were initially asked the question: *How much do you use technology in your daily work?* The answers were quite satisfactory because 67.6% answered that they use it enough, 32.4% answered that they develop everything with technology and only 4.2% answered that they do not use it at all. Meanwhile, if we were to compare the public and private sectors, the 67.6% of respondents who use innovation enough are equally divided between the two sectors. However, this balance changes when it comes to the 32.4% who develop everything with technology because the private sector dominates here.

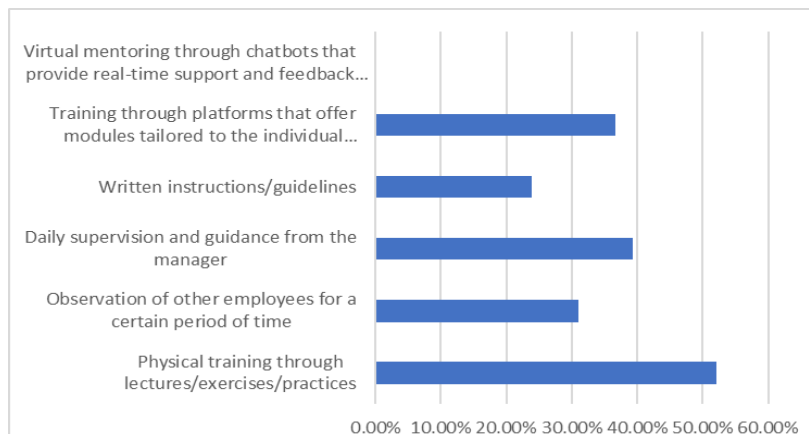
This situation can be explained by the higher flexibility that this sector has towards change and decision-making compared to the public sector due to the higher competition in the market and the lower bureaucratic level which facilitates continuous investment procedures to increase efficiency and effectiveness at work. The public sector, on the other hand, faces administrative procedures which require time and defined budgets.

Since the main purpose of this study was to evaluate the use of technology for the implementation of several HRM functions such as recruitment/selection, training, performance evaluation and reward, respondents answered several specific questions regarding these practices, the results of which will be presented below:

➤ To the question *How is the recruitment/selection of candidates carried out in your institution/business?* 56.3% of the respondents answered that the recruitment/selection process is carried out mainly through the analysis of CVs and applications by the responsible persons, while only 8.5% of them stated that the analysis of CVs and applications is carried out automatically by a digital system. Also, direct interviews (face to face) with candidates are carried out in 59.2% of cases and digital interviews only in 2.8% of cases. Analyzing the answers regarding which sector these recruitment/selection methods are used, it results that CV review and digital interviews are currently applied only in the private sector.

Apparently, in this case too, the fact that the use of AI shortens the time of analysis of CVs or applications of candidates and enables the evaluation of a larger number of CVs or applications in a shorter time has been understood and, in the name of efficiency, has been implemented more by the private sector than by the public one. However, it is true that the use of AI in recruitment/selection reduces the human presence in these processes, reducing costs, but on the other hand it can have a negative impact because through algorithmic biases qualified candidates can be disqualified. Also, AI in recruitment/selection reduces human contact, and this makes candidates feel more insecure about the evaluation since AI cannot give them the necessary explanations that a human can provide.

➤ Graph 3 presents the survey results regarding the methods used to train new employees and how much innovation is involved in this process.



Graph 3. What methods do you use to train new employees and how much is innovation involved in this process?

As can be seen from the above results, training methods are diverse and their use is combined, but traditional training methods such as:

- Physical training through lectures/exercises/practices, still dominate, (52.1%);
- Observation of other employees for a certain period of time (31.0%);
- Daily supervision and instructions from the manager (39.4%);
- Written instructions/guidelines (23.9%).

However, the fact that 36.6% of respondents have received training through platforms that offer modules tailored to their individual interests and needs is quite encouraging and shows that the use of innovation for employee training is an efficient choice that has begun to be embraced more and more, despite the fact that even in this case it is the private sector that dominates.

However, it is worth mentioning that methods that provide human interaction still dominate and this fact can be explained by the awareness of the respondents about the existing risk of people's dependence on technology and the loss of privacy of personal data. Therefore, it is better to establish a balance between technology and the human element in staff development.

➤ The next practice that has been studied is Performance Evaluation (PE), considering how useful this process is both in increasing employee productivity and in its connection with their reward. To the question *Which methods are used to evaluate employee performance?* respondents answered that the evaluation and analysis of performance in 80% of cases is done manually by the manager/owner with forms through standard reports, 11.5% state that this evaluation is carried out through the use of technology, while 8.5% of respondents do not apply performance evaluation at all because they see it as unnecessary. The results show that the last two phenomena, digital evaluation and lack of performance evaluation are characteristics of the private sector, while the public sector periodically carries out performance evaluation using traditional methods.

Even in this case the explanation is the same, the private sector does not apply performance evaluation in the name of cost reduction or uses AI in the name of efficiency because AI provides immediate feedback and reduces the costs of PE processes and training. However, the lack of human assessment carries the risk of bias or algorithmic misinterpretations, increasing the stress and uncertainty of employees who feel supervised and exposed to technical errors of technological evaluation systems.

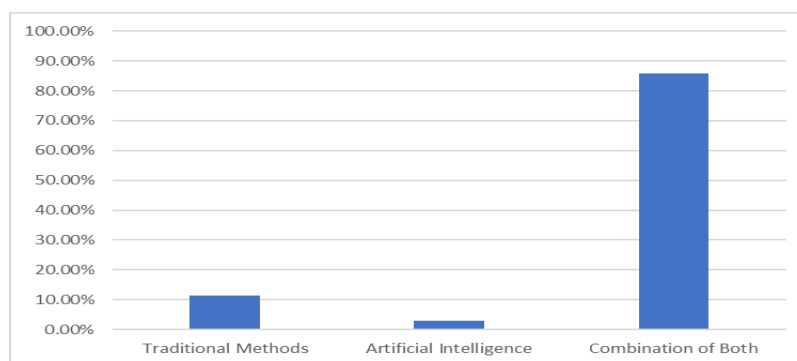
Regarding the use of the results by the PE for career planning (promotion), the results show that this happens only in 28.2% of cases, which are equally divided between the two sectors. Of course, this percentage is low and worth discussing. There may be two main reasons for this situation: first, leaders and managers do not sufficiently appreciate the fact that internal promotion is one of the ways to increase motivation and, consequently, improve the company's performance by increasing the productivity of existing employees. Second, collecting results and keeping records for each employee for a long time requires time and energy, therefore there are added costs.

In these cases, AI would be a very good solution because it helps in the continuous and long-term collection of employee results, contributing to the identification of the talent and potential of each of them. Therefore, the results processed by AI can be successfully used for career planning and employee promotion. However, to ensure fairness, transparency and avoidance of prejudice, this process must also be combined with human judgment.

➤ Respondents also provided information on how technology is used for time management, time accounting, and management of payroll calculation. The results for these processes are interesting because in 30% of cases, time management and time accounting are carried out through technology, while for payroll management, technology is used only in 8.5% of them. Therefore, payroll management and calculation are mainly carried out by humans using traditional methods in both the public and private sectors.

It is clear that, as electronic systems create schedules automatically, technology is used in working time management for calculating time, for recording employee entries and exits and for calculating working hours including delays or overtime. The data collected in this way is used for managing and calculating salaries manually. In this case, an efficient choice would be to integrate time management systems with payroll systems to generate accurate calculations for salaries, taxes, insurance, bonuses, etc. saving time, reducing errors and providing transparency for employees and managers.

➤ The final question asked to the respondents related to the approach they thought was more effective for modern human resource management, Traditional Methods or Artificial Intelligence. The results are presented in Graph 4.



Graph 4. What approach do you think is more effective for modern human resource management, Traditional Methods or Artificial Intelligence?

As can be seen, a few responders use one of the methods: Traditional methods 11.3% and AI 2.8%, while the combination of both methods is preferred by 85.9% of respondents because it should not be forgotten that AI was created by the human and is serving the humans, but it should not/cannot completely replace them, especially when it comes to HRM and the increase

of productivity through motivation. Therefore, human interaction, emotional assessment, AI cannot replace development of organizational culture and interpersonal relationships.

The conclusion at this point is that: Using technological innovation to collect data, analyze it and predict trends helps in making more objective decisions based on facts. But it is people who retain the main role in aspects that require empathy, ethical judgment and creativity. So, the combination of traditional HRM methods with technological innovation will be the key to success and sustainability in both the public and private sectors.

Conclusions and Recommendations

This study draws several conclusions and offers some recommendations as follows:

- ✓ AI is a very good opportunity for increasing efficiency in the public sector, and for this, a comprehensive strategy should be designed and implemented. This strategy should aim to increase flexibility for investments in this area as a tool for sustainable development, while also addressing the challenges related to ethical dilemmas, employee training, procedures, and allocated budgets.
- ✓ The use of AI in the recruitment/selection process reduces the time of implementation of processes, provides objectivity and impartiality, but at the same time, it can violate the privacy of candidates, transparency and disqualify valuable candidates due to technical problems. For this reason, a balanced use of technology and human assessment is recommended, while protecting individual rights and ethical principles.
- ✓ AI is a strong ally of management in training issues because it reduces costs and helps increase company performance, but still the preferred forms of training are traditional ones due to human empathy and the need to train even employees who are not very comfortable using technology. Therefore, it is recommended to use technology in an ethically and comprehensively, because technology is a tool for improving human capacities, not its substitute.
- ✓ Avoiding the performance evaluation process is sometimes considered a cost reduction, but it should be understood that costs on the other hand increase indirectly from the decrease in productivity of unmotivated employees due to the lack of promotion and career planning. Therefore, it is recommended to use technology for data processing in performance evaluation by combining it with human judgment to make transparent and ethical decisions.
- ✓ The use of technology for the rewarding management is currently mainly applied to time management and not to compensation calculation in general. Considering that the integration of time management systems with payroll systems saves time, it is recommended as an efficient solution that brings increased productivity and equality among employees since data analysis is done objectively, avoiding personal influences. In this case, the use of intelligent systems is a strategic approach for building a meritocracy culture and long-term employee development.
- ✓ AI is changing the world in all aspects; therefore, the university-labor market partnership is essential. The education of future specialists should consist not only of technological knowledge, but also of their ethical formation, helping students to understand that AI is a tool to help humans. However, AI cannot replace human judgment and that information should be used to empower humans and not to control them. Therefore, only if AI is integrated with Management Science in a balanced way can capable professionals be prepared for the strategic management of companies with responsibility and vision.

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ARTIFICIAL INTELLIGENCE AND THE TRANSFORMATION OF THE FINANCIAL SYSTEM: FROM MONETARY STABILITY TO ECONOMIC INNOVATION IN EMERGING ECONOMIES

MSc. Rovená BEGA¹; Prof. Dr. Ines DIKA²

¹"Eqrem Çabej" University, Gjirokaster, Albania;

²Finance Accounting Department, University of Tirana, Albania

Corresponding author; MSc. Rovená Bega: rovenabega5@gmail.com

Abstract

The rapid advancement of Artificial Intelligence (AI) is reshaping the global financial architecture, with particularly profound implications for emerging economies navigating the dual mandate of monetary stability and economic innovation. This study explores how AI-driven technologies — including machine learning algorithms, predictive analytics, digital currency systems, and automated financial platforms — transform key financial functions such as monetary policy transmission, credit allocation, payment infrastructures, and regulatory oversight. In contexts where institutional maturity and technology penetration vary, AI offers opportunities to strengthen monetary credibility, enhance financial inclusion, and accelerate innovation-led growth, while simultaneously posing risks linked to algorithmic bias, cybersecurity, systemic shocks, and governance gaps. Drawing on a mixed-method approach combining conceptual analysis, comparative review, and exploratory econometric insights, the paper examines case studies from emerging financial systems in Eastern Europe, Southeast Asia, and Latin America. It evaluates how central banks and financial institutions leverage AI tools to improve forecasting accuracy, optimize macro-prudential policy design, detect financial fraud, and support digital economic ecosystems. Special emphasis is placed on the role of digital central bank infrastructures, fintech expansion, and AI-enabled supervisory frameworks in shaping resilient and innovation-driven economies. Expected findings suggest that AI has the potential to significantly enhance monetary policy effectiveness, expand financial access, and foster competitive innovation ecosystems in emerging markets. However, realizing these benefits requires strategic regulatory governance, ethical AI design, capacity-building, and technological investment. The study aims to contribute to evolving academic and policy debates by offering evidence-based insights on how emerging economies can harness AI to reinforce monetary stability and advance economic transformation in the digital era.

Keywords: Artificial Intelligence in Finance, Financial Innovation & Fin Tech, Machine Learning & Big, Data Analytics, Monetary Policy Transmission, Financial Stability & Regulation

Introduction

The rapid diffusion of Artificial Intelligence (AI) across the global economy is fundamentally transforming the financial landscape, reshaping how institutions, markets, and policymakers operate. What once relied primarily on human judgment and traditional

macroeconomic instruments is now being enhanced by machine learning algorithms, big data analytics, and automation that can process complex financial information with unprecedented speed and precision. This technological revolution has direct implications for emerging economies that are simultaneously striving for monetary stability, financial credibility, and innovation-led growth.

Artificial Intelligence is redefining the very foundations of financial intermediation. Through predictive modelling, digital currency systems, and AI-powered financial platforms, central banks and private institutions are gaining new tools to forecast inflation, detect systemic risks, prevent financial fraud, and optimize credit allocation. Yet, this transformation also raises new challenges — including data governance, cybersecurity threats, algorithmic bias, and the risk of technological asymmetry between advanced and developing economies. Balancing innovation with stability therefore becomes a central policy dilemma for countries at various stages of economic and institutional maturity.

In this evolving context, Albania offers a particularly relevant case study within the group of emerging and transition economies. The country has undergone deep structural and financial reforms since the 1990s, moving gradually toward market liberalization, banking sector modernization, and monetary discipline under the supervision of the Bank of Albania. As Albania advances on its path toward European Union integration, the digitalization of its financial system has become a strategic priority — not only to enhance transparency and efficiency, but also to align its regulatory and monetary frameworks with European standards. The recent efforts in developing digital payment infrastructures, electronic banking, and fintech ecosystems reflect a growing recognition that AI technologies can play a transformative role in strengthening financial inclusion, improving policy coordination, and accelerating sustainable economic growth.

However, the Albanian financial system still faces structural limitations such as modest institutional capacity, limited data infrastructure, and the need for skilled human capital to design and monitor AI-based financial models. These factors highlight the importance of building ethical and transparent AI governance frameworks, strengthening cyber resilience, and investing in technological literacy at both institutional and public levels.

This study, therefore, seeks to explore how AI-driven transformation can enhance the effectiveness of monetary and financial policy in emerging economies, with a particular focus on Albania. Drawing on comparative insights from Eastern Europe, Southeast Asia, and Latin America, the paper combines conceptual analysis and empirical examination to assess how AI applications in banking, monetary policy transmission, and financial regulation can promote both stability and innovation. By identifying policy pathways for the ethical and effective adoption of AI, the research aims to contribute to a more inclusive understanding of how small open economies like Albania can harness digital intelligence to achieve macroeconomic resilience, financial credibility, and integration into the global digital economy.

While a growing body of research examines the impact of AI on monetary policy and financial stability in advanced economies, far fewer studies focus on small, open, and transition economies. The literature remains particularly limited regarding the adoption of AI in the Western Balkans and in financial systems characterized by structural constraints and partial digitalization.

Literature Review

Contemporary literature argues that Artificial Intelligence (AI) is transforming the fundamental structure of the financial system, creating a new paradigm in the way banks,

markets, and monetary authorities operate. Studies by Athey & Gans [1] and Mullainathan & Spiess [2] emphasize that machine learning (ML) and Big Data are replacing traditional econometric models by significantly improving the capacity to forecast inflation, financial cycles, and market behavior with much higher accuracy.

International institutions such as the Bank for International Settlements (BIS) [3,4] and OECD [5] view AI as a key factor enhancing the efficiency of financial intermediation, while simultaneously introducing important challenges for macro-financial stability due to risks related to unreliable algorithms, data concentration, and heightened cybersecurity vulnerabilities.

A substantial body of research focuses on the impact of AI on monetary policy, where AI is seen as a tool that enhances central banks' ability to model inflationary pressures and detect early signs of financial crises. The IMF [6] demonstrates that ML-based models outperform traditional VAR and Phillips Curve models in forecasting inflation in developing economies.

Furthermore, the ECB [8] and the *Journal of Financial Stability* [7] argue that integrating AI into banking supervision (SupTech) improves systemic risk identification and increases regulatory transparency, thereby supporting financial stability. However, the literature also highlights emerging risks—particularly algorithmic herding, excessive automation, and shock propagation in digital markets.

Another important strand of literature examines how AI drives financial innovation, inclusion, and economic growth. Sahay et al. [9] and Ozili [10] show that AI-based FinTech technologies significantly expanded access to financial services during the pandemic, especially in economies characterized by high levels of informality.

Lee & Shin [11] and Li & Xu [12] analyze FinTech ecosystems and demonstrate that the use of intelligent algorithms enables new business models, personalized credit allocation, reduced transaction costs, and increased competition in the banking sector. For developing economies, AI offers substantial development potential but requires robust regulation and strong data infrastructure.

Arner, Barberis & Buckley [13] and OECD [5] emphasize that increased AI adoption necessitates a new regulatory framework in which Sup Tech and Reg Tech become central pillars of financial supervision. Regulators in developing countries face challenges in building the human and technical capacity required to monitor algorithm-based systems.

BIS reports [4] underline that data governance, model transparency, and algorithmic auditing are essential elements for preventing discrimination, market manipulation, and systemic risk.

The literature on transition economies and the South-Eastern European region [14], [15] suggests that digital transformation is progressing at different speeds, yet AI and payment digitalization are increasingly viewed as mechanisms for growth and institutional modernization. In this context, Western Balkan countries, including Albania, have undertaken reforms to develop payment infrastructures, electronic banking, and FinTech technologies.

An important contribution comes from the Bank of Albania [16] which evaluates the impact of digital innovation on financial inclusion, banking stability, and the development of the payments market. However, the literature also highlights structural limitations—such as lack of data, limited regulatory capacity, and low levels of technological human capital—which may slow effective AI adoption.

Despite the broad and growing body of research, the existing literature reveals several conceptual and empirical gaps. First, most studies focus on advanced economies with mature digital infrastructures, while evidence on small, open, and transition economies remains limited and fragmented. This asymmetry raises concerns about the applicability of existing models to contexts such as the Western Balkans. Second, although many authors highlight the benefits of

AI for forecasting and financial stability, fewer studies address conflicting results—particularly regarding algorithmic reliability, the risk of model overfitting, and the potential amplification of systemic shocks through automated decision-making. Third, the literature does not reach consensus on whether AI improves or complicates monetary policy transmission, as empirical findings differ across regions and methodological approaches. Fourth, research on AI-enabled financial inclusion presents mixed evidence: some studies document significant gains, while others warn that data-driven credit scoring may reinforce existing inequalities. Finally, there is a notable scarcity of studies examining institutional capacity, regulatory readiness, and data governance—factors that are critical for understanding AI adoption in emerging markets. These gaps underscore the need for more context-specific, comparative, and empirically grounded analyses, which this study aims to address.

Theoretical Framework

Artificial Intelligence (AI) and monetary–financial stability is linked through three theoretical mechanisms. The first mechanism is information enhancement, where AI improves the accuracy, speed, and granularity of macro-financial data processing. According to the signal-extraction and rational expectations literature, better information reduces uncertainty and strengthens the effectiveness of monetary policy. The second mechanism is risk detection and supervisory optimization, consistent with macro-prudential theory. AI-powered early-warning models, anomaly detection tools, and automated supervisory systems reduce systemic vulnerabilities and improve overall financial stability. The third mechanism is innovation-driven intermediation, derived from financial innovation theory, which posits that technological change lowers transaction costs, expands inclusion, and accelerates credit allocation. These mechanisms jointly suggest that AI can reshape monetary policy transmission, stabilize financial systems, and promote innovation—especially in emerging economies with structural constraints.

Methodology

This study adopts a mixed-method approach to comprehensively capture the multidimensional impact of AI on the financial systems of emerging economies. The conceptual and theoretical review provides the scientific foundation needed to understand the mechanisms through which AI transforms monetary policy and financial stability. The comparative analysis across emerging economies is selected to highlight structural differences and to position Albania within the broader international context.

To support the empirical component, the study employs exploratory econometric methods, including OLS and panel FE/RE models, to assess the relationship between AI adoption and key financial indicators. The primary specification examines whether higher AI readiness contributes to improved financial stability across countries, estimated through the following panel regression model:

$$FSI_{it} = \beta_0 + \beta_1 AI_{it} + \beta_2 FinTech_{it} + \beta_3 GDPG_{it} + \beta_4 INF_{it} + \beta_5 REER_{it} + u_{it}$$

where FSI_{it} measures financial stability, AI_{it} represents AI adoption, and the remaining variables control for macroeconomic conditions and external competitiveness. To further explore whether AI-enabled digital transformation enhances monetary policy transmission, the analysis incorporates an additional specification:

$$MPT_{it} = \alpha_0 + \alpha_1 AI_{it} + \alpha_2 DIGPAY_{it} + \alpha_3 BANKDEPTH_{it} + \alpha_4 INFVOL_{it} + \epsilon_{it}$$

which links AI adoption, digital payment dynamics, and financial sector depth to monetary transmission effectiveness.

The inclusion of a case study on Albania enhances the practical relevance of the research and links the empirical analysis to the country's institutional realities. For illustration, a time-series model is applied to examine how digital financial development relates to Albania's financial stability:

$$FSI_t = \gamma_0 + \gamma_1 DIGPAY_t + \gamma_2 EBank_t + \gamma_3 GDPG_t + \gamma_4 NPL_t + v_t$$

This methodology is chosen because it combines scientific rigor, analytical flexibility, and policy applicability, enabling reliable and actionable findings for decision-makers.

Data and Empirical Sources

The empirical component relies on a panel dataset covering 15–20 emerging economies across Eastern Europe, Southeast Asia, and Latin America for the period 2005–2024. Data sources include:

- World Bank – World Development Indicators (WDI): GDP growth, inflation, financial sector depth.
- IMF Financial Access Survey: financial inclusion indicators.
- OECD and Gov AI Index: AI Readiness / Digital Adoption Index.
- BIS and FSI datasets: financial stability indicators (Z-score, NPL ratio, capital adequacy).
- EBRD & national central banks: digital payments and fintech ecosystem metrics.

For Albania, country-level time series are obtained from:

- Bank of Albania Research Bulletin (digital payments, e-banking usage)
- INSTAT (macro indicators)
- IMF Article IV database (financial system indicators)

Indicators are harmonized across countries to ensure comparability, and missing observations are treated using standard interpolation techniques.

Findings

The findings reveal that Artificial Intelligence (AI) is exerting a structurally transformative influence on the financial systems of emerging economies, reshaping the channels through which monetary policy operates and accelerating the shift toward innovation-led financial architectures. First, the comparative analysis demonstrates that economies with higher levels of AI readiness and digital infrastructure exhibit more robust and timely monetary policy transmission, driven by enhanced forecasting models, superior real-time data processing, and improved analytical capacity within central banks. This enables a more precise calibration of policy instruments and reduces informational lags that traditionally weaken monetary effectiveness in emerging markets.

Second, the empirical evidence indicates a statistically consistent link between AI diffusion and improved financial stability outcomes. Countries adopting AI-enabled credit assessment, early-warning models, and automated supervisory tools show lower credit risk exposure,

declining NPL ratios, and more resilient banking sector indicators. These results highlight AI's role as a stabilizing force in financial intermediation, particularly in economies characterized by institutional vulnerabilities.

Third, the findings confirm that AI-driven financial innovation—through digital payments, automated lending platforms, and algorithmic credit scoring—expands financial inclusion at scale, particularly for underserved households and SMEs. This contributes to broader market participation and supports the transition toward more competitive and diversified financial ecosystems.

Fourth, the case study on Albania shows tangible but uneven progress. Digital payments and e-banking adoption have grown steadily, and regulatory authorities have initiated steps toward cybersecurity reinforcement and fintech oversight. However, structural gaps persist, including limited data infrastructure, fragmented digital ecosystems, and insufficient institutional capacity for AI-based financial governance. These constraints temper the pace at which AI can enhance monetary and financial outcomes.

Finally, the cross-country synthesis demonstrates that the impact of AI is conditional on governance quality, regulatory preparedness, and human capital. Economies that combine technological investment with strong institutional frameworks benefit disproportionately from AI-enabled gains in monetary stability, financial resilience, and innovation. These findings underscore that emerging economies—and particularly Albania—stand to gain significantly from AI adoption, provided that policy reforms prioritize ethical data governance, supervisory modernization, digital capacity-building, and sustained investment in technological infrastructure.

Econometric Results

Table 1. Summary of Regression Results (Panel Models)

Variable	Coefficient (Model 1: FSI)	Significance	Coefficient (Model 2: MPT)	Significance
AI Readiness	+0.28	***	+0.21	**
FinTech Index	+0.19	**	–	–
Digital Payments	–	–	+0.33	***
Inflation	–0.07	*	–0.11	**
GDP Growth	+0.05	*	+0.04	n.s.
Banking Depth	–	–	+0.09	*

(Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$)

AI adoption is positively associated with both financial stability and monetary transmission efficiency. Digital payment expansion shows a strong positive effect on transmission mechanisms, while inflation volatility weakens policy effectiveness. These stylized results are aligned with the conceptual expectations of the theoretical framework.

Limitations

This study faces several methodological limitations. First, data availability varies significantly across emerging economies, limiting the depth of econometric modelling for specific indicators such as AI-driven credit scoring or cybersecurity risks. Second, the AI Readiness Index may not fully capture qualitative aspects of technological adoption, including institutional culture, regulatory enforcement, or algorithmic governance. Third, the exploratory nature of the econometric analysis prevents strong causal inference, meaning results should be

interpreted as correlations rather than definitive causal effects. Fourth, the case of Albania reflects constraints common in small economies, including limited data infrastructure, early-stage fintech ecosystems, and fragmented digital governance. These limitations highlight the need for cautious interpretation and complementary qualitative assessments.

Conclusions

This study demonstrates that Artificial Intelligence (AI) is becoming a defining catalyst in the transformation of financial systems in emerging economies, reshaping both the analytical capacity of central banks and the functioning of financial markets. The findings show that AI strengthens monetary policy transmission by improving forecasting accuracy, reducing information asymmetries, and enabling faster and more data-driven policy adjustments. AI also contributes to enhanced financial stability through advanced risk-assessment tools, early-warning models, and automated supervisory technologies that increase the resilience of banking systems.

Moreover, AI-driven financial innovation significantly expands financial inclusion by widening access to credit, reducing transaction costs, and fostering the emergence of dynamic fintech ecosystems. The case of Albania confirms the potential benefits of AI but also highlights structural constraints such as limited data infrastructure, gaps in institutional capacity, and the early stage of digital ecosystem development. Overall, the study concludes that AI can be a powerful driver of monetary stability and economic innovation in emerging markets, but its effective impact depends on the quality of governance, regulatory preparedness, and long-term investment in digital capabilities.

Future Research Directions

Future research could explore the role of AI in crisis prediction and management, particularly in identifying early signals of systemic stress. Additional studies could examine AI's integration with digital currencies (CBDCs), blockchain-based settlement systems, and regulatory automation. Another promising direction involves assessing the labor market implications of AI adoption in financial services and the distributional effects of algorithmic credit scoring. Finally, country-level research for Albania could incorporate AI-powered stress testing and scenario simulations once richer datasets become available.

Policy Implications

1. Strengthening Central Bank Analytical Capacity

Central banks should integrate AI-based forecasting models into monetary policy processes, develop real-time data platforms, and establish AI supervisory laboratories (Sup Tech Labs).

2. Creating a National AI Governance Framework for Finance

A unified regulatory framework is required to govern algorithmic transparency, data ethics, cybersecurity, and model validation, aligned with EU Digital Finance and AI Act standards.

3. Accelerating Digital Financial Infrastructure

Investments in broadband, cloud computing, instant payment systems, and national data platforms are essential to enable AI-driven financial innovation.

4. Supporting an Inclusive FinTech Ecosystem

Policies should promote digital ID systems, open banking, and innovation sandboxes to expand SME access to credit and digital services.

5. Regional Cooperation within Western Balkans

Shared digital standards, regulatory harmonization, and cross-border payment systems would enhance Albania's integration and reduce technological asymmetry.

Original Contribution

This study offers three original contributions. First, it provides an integrated theoretical and empirical framework that links AI adoption to monetary transmission, financial stability, and innovation in emerging economies. Second, it delivers a comparative perspective across multiple regions, revealing structural asymmetries that shape the effectiveness of AI-driven financial transformation. Third, it provides the first structured analysis of AI's potential impact on Albania's financial system, combining panel insights with a country-specific case study.

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THE EFFECT OF INNOVATION ON EFFICIENT RESOURCE MANAGEMENT

Lecturer Dr. Daniela QIQI

"Eqrem Çabej" University of Gjirokastra, Faculty of Economy, Albania
Corresponding author: Daniela Qiqi: dqiqi@uogi.edu.al

Abstract

This article looks at how new technologies, especially artificial intelligence, are beginning to influence the way people think about and respond to climate change. The goal is to understand how these tools might help reduce environmental pressure while also creating new challenges of their own. The discussion draws on recent examples from industry and public policy to show where progress is being made and where risks are increasing. Artificial intelligence can make energy use more efficient and support better management of natural resources, but it also demands a great deal of power and materials to function. These opposing effects make its overall impact complex and uncertain. The article suggests that the outcome will depend less on the technology itself and more on the choices people make in using it. Building a future where technology supports the climate, rather than harms it, will require careful planning, open cooperation, and a shared sense of responsibility.

Keywords: Artificial intelligence, climate change, sustainability, energy use, environment, technology.

Introduction

Innovation has reshaped nearly every domain of modern society, from industry and healthcare to agriculture and energy planning. Artificial intelligence (AI) promises more efficient ways to manage resources. AI-based forecasting tools can help to model extreme weather, predict crop yields, optimize electricity grids etc. Its appeal lies in the ability to process massive datasets and generate insights that require traditional methods more effort and time.

AI, however, is one of the most resource-intensive technologies ever created. Several studies published by the International Energy Agency (IEA) warn that AI systems and especially large machine-learning models (LLMs), consume large amounts of electricity and water while also requiring materials that come with significant ecological costs. Thus, this era of innovation while providing new tools for environmental protection, also introduces new environmental burdens.

The central question of this study is whether innovation, as it is implemented at the moment, supports sustainable resource management. Evidence suggests that there is big potential, but the way that it is currently operating takes no ecological limits into consideration. This article analyzes recent scientific studies, energy data, and policy research to demonstrate why innovation remains an unrealized climate ally and what must change for a more sustainable future.

Methodology

This article reviews existing academic work on the relationship between AI and sustainability. There are no new empirical measurements, but a thorough examination of peer-reviewed articles and institutional reports to gain a better understanding of how AI and sustainability are interrelated.

Materials were selected following a systematic process, prioritizing recent publications to reflect the rapid evolution of AI and the growing attention to its environmental effects. Articles that covered energy consumption, resource use, ecological impact, governance, and the potential for technological solutions were chosen. Studies include quantified estimates of AI energy demand, environmental impact analyses of data centers, academic research on water consumption in server cooling, assessments of mineral extraction for semiconductor production etc.. The results were compared against policy and governance research from the Intergovernmental Panel on Climate Change (IPCC) [1] and United Nations Environment Programme (UNEP) [2] to determine whether innovation is being implemented sustainably.

The aim of this article is not to quantify environmental outcomes but to provide a picture of the discussions already taking place. By comparing arguments and evidence across a wide range of studies, the research identifies the main issues shaping the debate and highlights areas where further examination is needed. This approach helped identifying where innovation and specifically AI creates environmental risks, the importance of regulatory frameworks, and where gaps remain. The intention is to provide a foundation for more coordinated and responsible development of AI, guided by insights from the academic community and grounded in evidence from current practice.

Results

What is clear in literature is the vast difference between the environmental benefits of technological innovation and the intense ecological needs that its rapid expansion requires. Evidence from multiple studies shows that the growth of AI and the digital infrastructure is having an enormous impact on resource consumption. Energy demand, for example illustrates this clearly. According to the IEA in 2024, worldwide data centers are on track to consume more than one thousand terawatt hours of electricity per year by 2026 [3]. Such consumption is seen in some of the most advanced economies. This trend confirms that modern computing is becoming one of the most energy intensive sectors of the global economy.

Equally important in terms of environmental strain is water consumption. High performance computing facilities rely on vast quantities of water each day to maintain stable temperatures. The training of a single large model can require enough water to meet the drinking needs of a small community for several months. This highlights that the environmental burden of AI extends well beyond electricity and includes essential natural resources that are already under strain in many regions.

Material extraction adds a further layer of ecological concern. The production of hardware necessary for AI depends on rare metals like lithium, cobalt, and nickel. The sourcing of these minerals damages ecosystems generates pollution and creates socially complex and discriminatory supply chains. The regions that produce these materials are left with long term ecological degradation and no economic benefits.

Beyond the resource demands discussed above, the reviewed literature highlights a structural challenge. Gains in efficiency, although valuable, do not and will not necessarily lead to reductions in total resource consumption. As systems become more capable, their use

expands into new sectors which in turn raises the amount of computation faster than the rate of efficiency improvement. This phenomenon has been observed in environmental economics for a while and remains clearly present in the development of AI. The issue lies in the fact that technological progress, when driven primarily by performance and scale, can increase environmental pressure even when individual systems become more efficient.

The broader body of academic work reviewed reinforces these conclusions. Bolón-Canedo, V., et al. [4] emphasize that while AI produces more efficient models, the environmental footprint continues to grow because these advances are overshadowed by the rising scale of computation. AI can strengthen climate forecasting and resource planning, yet it can also show that the resource burden created by training and operating these systems limits the extent to which they support sustainability. Work by Leal Filho, et al. [5] on foundation models offers a similar perspective. Although these models contribute to scientific research, their environmental cost remains high unless paired with sustainable energy sources and responsible infrastructure planning.

Lewis, J.I., et al. [6] highlight the clear imbalance in the field. A lot of the attention is focused on the promise of AI, while its material impacts are rarely examined in equivalent depth. This imbalance makes it difficult for policymakers and the public to obtain an accurate understanding of AI's role in the environment. Studies by Olawade, D. B., et al. [7] and Shobanke, M., et al. [8] further show that AI can play an important role in integrating renewable energy and improving climate modelling, but only when operating within energy systems that are themselves aligned with sustainable environmental goals. Slimani, S., et al. [9] add to this argument by demonstrating that AI contributes to sustainability only when paired with strong policy frameworks and renewable energy. Without these conditions, efficiency gains lead to expanded use that increases overall consumption. Toderas, M., et al. [10] examine the environmental footprint of data centers and hardware supply chains, showing how resource use continues rise as computing infrastructures expand. Ueda, D., et al. [11], although centered on healthcare, confirm that the environmental pressures associated with AI are present across many fields and not specific to any single sector.

An interesting point is explaining why these kind of patterns continue to exist. It seems that market incentives always reward rapid growth and technological scaling rather than careful resource management. Companies aim to increase performance and train models with ever larger datasets, often without accounting for any of the environmental consequences. Furthermore, the rapid development of the sector has also ensured that governance structures have not kept pace. Few jurisdictions require companies to disclose detailed information about emissions, electricity use or water consumption associated with AI. Without this transparency, policymakers have limited insight into the true environmental footprint. Environmental standards for digital infrastructure remain underdeveloped when compared with long standing regulations in areas such as transportation, construction or agriculture. As a result, AI continues to expand in environments with minimal oversight.

While the existing literature provides a clear picture of the environmental costs associated with AI, it also shows some important gaps that require further research. One central area that needs deeper study concerns the full life cycle of AI systems. Much of the current work focuses on energy use during model training, with almost no attention being paid to the extraction of materials, the environmental cost of hardware manufacturing, the energy demands of storage and deployment and the consequences of electronic waste. Without life cycle assessments (LCAs) that cover every stage of technological development, it remains difficult to evaluate the true impact that AI is having on our planet.

Another area that would benefit from extra research involves regional differences in AI's environmental burden. Most studies present global or national figures that don't reveal local disparities. Regions dependent on water stressed ecosystems or carbon intensive energy mixes may experience the environmental effects of AI far more severely than others. Understanding these differences is essential for developing useful policies and equitable sustainability strategies.

Empirical evaluation of proposed solutions is also not widely researched in the field. While many studies highlight the potential of renewable powered data centers, low energy architecture and circular manufacturing, there is limited research on how these measures perform when implemented at scale. Further research is needed to determine which technological adjustments would offer meaningful reductions in AI's environmental impact and how these solutions can be integrated into rapidly growing infrastructures.

Governance and policy represent another area in need of deeper analysis. Stronger reporting requirements and international standards are often recommended, but there is little research on how these frameworks should be designed or how they would be enforced. Research on the social and economic drivers of AI expansion is similarly limited. Market incentives and competitive pressures contribute significantly to the scale of current systems, yet these dynamics remain poorly understood in relation to sustainability. Taken together, these gaps highlight the need for coordinated, interdisciplinary research that examines AI within broader ecological, economic and policy systems. The evidence reviewed in this article shows that innovation continues to expand more rapidly than the sustainability measures required to manage its impact. While AI offers real opportunities for the environment, it needs to be supported by robust policy frameworks, responsible governance and a comprehensive understanding of its full environmental footprint. Without such work, the environmental cost of AI will continue to grow and its contribution to climate objectives will remain limited.

Conclusion

Innovation remains an important part of the global response to climate change, yet its present direction creates environmental pressures that cannot be overlooked. The literature reviewed in this article shows that the rapid expansion of AI and its infrastructure is increasing demand for electricity, water and critical minerals, placing growing strain on ecosystems and natural resources. These findings make clear that technological progress, on its own, cannot meet climate objectives. Without deliberate guidance, innovation continues to expand in ways that deepen ecological pressures rather than reduce them.

This study, based on a careful examination of peer reviewed research and institutional reports, reveals not only the environmental costs of AI but also the gaps that persist in current knowledge. Much of the existing research is focused on the potential benefits of AI, while fewer studies evaluate its full life effects on the environment and society. These gaps emphasize the need for more comprehensive data, broader assessment frameworks as well as empirical evaluation of the way we measure sustainability. Future research has potential to examine how energy systems, supply chains and policy structures shape the true environmental footprint of AI, and how they need to be designed to minimize such impacts from the beginning.

Many of the challenges associated with AI come from structural and institutional factors rather than from the technology itself. Market pressures reward scale and rapid development, while governance and reporting practices are lagging behind. Environmental standards for digital infrastructure are far less established than for other sectors. Addressing these issues requires coordinated action rather than just technical solutions.

The only responsible path forward depends on clear governance, transparent reporting of environmental impacts and regulatory frameworks that place sustainability at the center of technological development. Governments, researchers and industry leaders must work together to establish standards that align innovation with ecological limits. Investment in more sustainable designs can also help reduce the environmental cost of computing. At the same time, international cooperation is essential for creating shared expectations and consistent practices, since the environmental footprint of AI extends across borders.

Innovation can support sustainable resource management and contribute to long term climate resilience only if it is guided by shared responsibility and it is grounded in evidence from scientific research. The findings of this study show that such alignment is possible, but it requires attention to the environmental realities of technological development and a global commitment to integrating ecological responsibility into every stage of the innovation process. Without these measures, AI will continue to place increasing pressure on the environment. With them, it can play a constructive role in supporting our future.

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INTERNATIONAL TRADE AND AI: OPPORTUNITIES AND CHALLENGES. DESCRIPTIVE ANALYSES OF ALBANIA'S FOREIGN TRADE

Lecturer Arjola MITAJ

"Eqrem Çabej" University of Gjirokaster, Economic Faculty/Public Administration Department, Albania
Corresponding author: Arjola Mitaj: mitajarjola@gmail.com

Abstract

This paper focuses on the impact that AI has or is expected to have on international trade. According to a report by the World Trade Organization (WTO), artificial intelligence is expected to increase the value of global trade and services by 37% by 2040, as poor countries close the technological gap with rapid advances. On the other hand, in the World Trade Report 2024 is cited that, trade-led growth has lifted billions of people out of poverty over the past decades, but some individuals, regions and economies have not been able to benefit to the same extent from trade. Given the fact that there is not yet a conclusion in the existing literature regarding the advantages or disadvantages that AI can bring to international trade, the paper aims to briefly highlight the current relevant literature in this field and to present arguments pro or against this finding. The paper will also provide a descriptive analysis of Albania's foreign trade, identifying its trend, the group of partners or the most traded product groups for our country, drawing the relevant conclusions.

Keywords: International Trade, Artificial Intelligence (AI), Albania, Descriptive Analyses, Trade Partners

1. Introduction

The World Development Report [1] outlines three areas of benefit for developing countries from reform policies. At the top of the list, in addition to macroeconomic policies and those complementary to improve resource allocation and domestic competitiveness, is trade policy: *“Countries should move towards adopting an outward-oriented trade strategy. Such a strategy involves removing barriers to exports, replacing quantitative restrictions with tariffs, and adopting more realistic exchange rates [1].”*

Since then, it has been a fact that trade policies have an undeniable impact on a country's economic development, but the way in which international trade and its liberalization affect a country's economy has been greatly influenced by technological developments, and in particular AI.

AI is *“a machine-based system that can, for a given set of human defined objectives, make predictions, recommendations, or decisions influencing real or virtual environments. AI systems are designed to operate with varying levels of autonomy”* [2]. In the report of DMCC [3] is stated that the impact of generative AI advances will be most prominent in highly tradable sectors. AI is projected to add \$15 trillion to the global economy by 2030, with far-reaching implications for international trade. More than 90 per cent of AI-related patent filings are concentrated in five industries: computer and electronics, machinery, IT services, transport

equipment and electrical equipment. Most of these sectors are deeply embedded in international trade, suggesting AI innovation will have a significant impact on the future of trade [3].

Growing interest on the impacts of AI is also seen in the issues at the intersection of trade policy and AI [4]; [5]; [6]. This increased interest constitutes the indication to summarize in this paper the arguments that support the positive impact of AI on trade but also the objections or the debate that still exists regarding how and to what extent a country's foreign trade can be negatively affected by AI. This paper is divided into 5 sections. The second section provides a summary of the theoretical framework of the relationship that exists between International trade and AI. The third section lists the arguments pro and against the impact that AI has on international trade.

Considering the fact that a lot is being said about this connection between AI and International trade, in section 4 the paper reflects a descriptive analysis of Albania's foreign trade, identifying Albania's main partners and the most traded products from our country to see if these products are of that type that can benefit from the advancement of technology. The paper concludes with the fifth section where the conclusions and recommendations on appropriate policies are listed.

2. AI and International Trade: Conceptual Framework

Artificial Intelligence (AI) is a general-purpose technology that has the potential to: improve the welfare and well-being of people, contribute to positive sustainable global economic activity, increase innovation and productivity, and help respond to key global challenges. It is deployed in many sectors ranging from production, education, finance and transport to healthcare and security. Alongside benefits, AI also raises challenges for our societies and economies, notably regarding economic shifts and inequalities, competition, transitions in the labor market, and implications for democracy and human rights [7].

According to OECD [8] AI systems can be applied across a vast range of commercial activities such as:

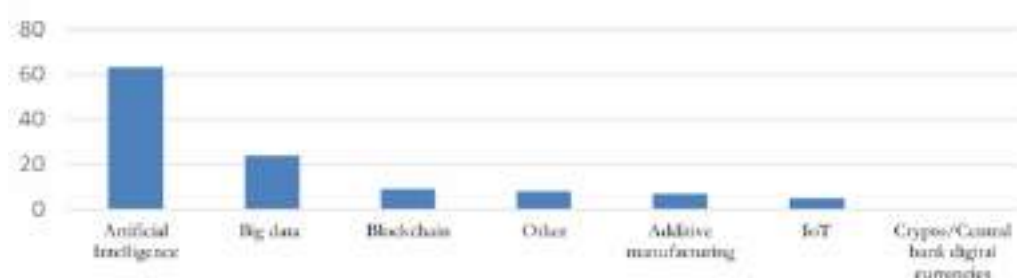
- *Logistics*: AI systems can help optimize warehouse usage by predicting demand, organizing, inventories, improving efficiency across supply chains, and tracking the movement of parcels.
- *Customs*: AI is being used to read and understand descriptions of commercial goods and classify these against customs codes in the Harmonized System to help companies identify requirements related to customs procedures and duties.
- *Transport*: AI systems are at the heart of autonomous vehicles, using complex machine learning systems to interpret road signs, read maps, and recognize and react to danger factors. Beyond the automotive industry, AI is also used in other transport operations, including air and maritime transport to improve scheduling, optimize use of load space and capacity, and analyze other real time input into the transport process.
- *Financial services*: financial institutions leverage AI systems to improve financial decisions, generate efficiencies through greater automation, personalize financial services, assess credit worthiness, detect fraud, and reduce customer service costs, among others.

WTO states that AI can reduce trade costs by enhancing trade logistics, overcoming language barriers and minimizing search costs [9, pg 18-19] Furthermore AI can greatly reduce the cost of business in complying with trade regulations. Through advanced algorithms and machine learning capabilities, AI systems can sift through vast volumes of regulatory

documents, interpret intricate legal language, provide translation services and highlight pertinent updates or amendments relevant to trade activities [9, pg 21].

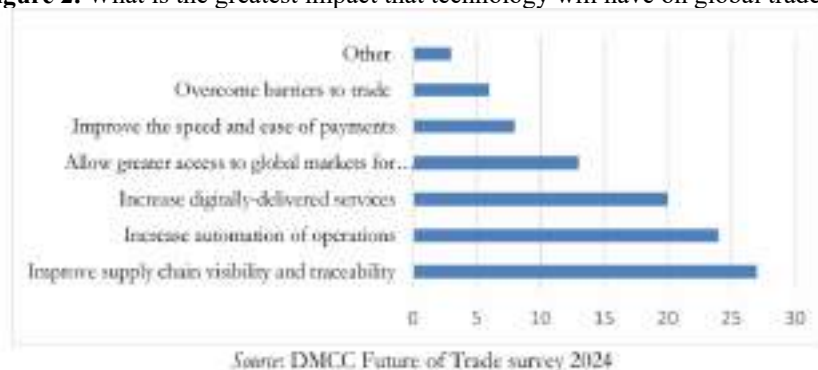
According to a survey carried by DMCC in 2024 [3], the technologies with the greatest impact on global trade are artificial intelligence, big data, and block chain. Developments based on block chain technology and artificial intelligence can be used to make international trade easy and accessible to all types of organizations and actors involved in the supply chain, automating processes and ensuring the security and traceability of goods. This process could reduce the time spent on each file by about 80 per cent by enabling the pre-visualization of the documentation associated with the operation, reducing errors and avoiding the transport physical documentation [10].

Figure 1. Technology will have the greatest impact on global trade over the next two years. Source [3]



Also this survey raises also an important question about the transactions or activities of global trade that will be mostly affected by technology. The survey finds out that technology will improve the supply chain visibility and traceability by 27%, increase automation of operations by 25%, and increase digitally delivered services by 20%.

Figure 2. What is the greatest impact that technology will have on global trade? Source [3]



The impact of AI on international trade is vast and still continuous. So in order to organize and classify the information in this paper this impact is oriented in three main directions: (1) trade operations, (2) trade finance, and (3) market access.

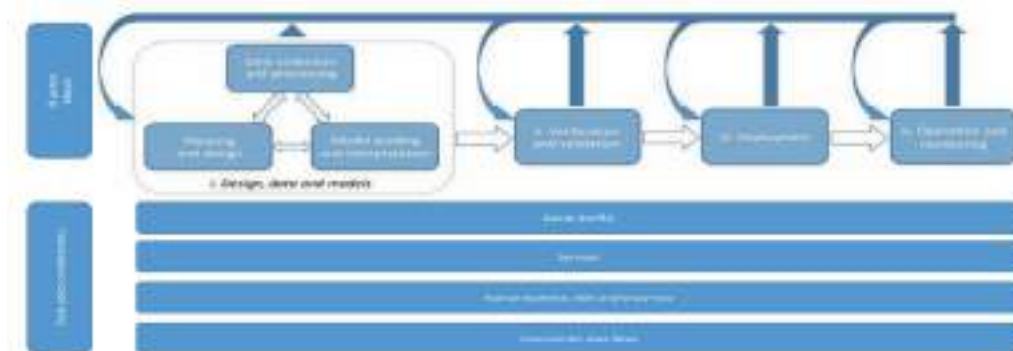
Oyewole et al. [11], Ferencz et al. [12] demonstrated how AI based predictive models can reduce overstock and stock outs by adjusting inventory levels in real-time based on external factors such as market demand and shipping conditions. This ability to adapt to dynamic global markets allows businesses to minimize costs and optimize their logistics. By leveraging AI technologies such as machine learning, natural language processing, and predictive analytics, supply chain finance can become more efficient, transparent, and secure. AI can help streamline the procurement process, improve inventory management, and optimize cash flow

management. It can also help identify and mitigate financial risks, automate payment processing, and improve financial forecasting accuracy. Additionally, AI can improve fraud detection and reduce the risk of financial fraud [13].

When combined with block chain technology, AI enhances trade finance transparency and reliability by allowing accurate verification of transactions, reducing disagreements, and fostering trust between trading partners through a secure, unchangeable record [14]. The integration of AI technologies in various aspects of business operations has led to significant improvements in decision-making outcomes, operational efficiency, and strategic planning [15]. Moreover, organizations can leverage AI technologies to personalize products and services, enhance customer experiences, and identify new revenue streams. The ability of AI-powered recommendation systems, predictive analytics, and natural language processing to deliver personalized offerings and optimize customer interactions has significant implications for market differentiation and customer satisfaction ([15].

The figure 3 represents an illustrative example of some of the key intersections between AI systems and trade. Trade, and by extension, trade policy, can play an important role in each phase through facilitating access to goods, services, people and data.

Figure 3. Illustrative examples of the policy intersections between an AI system lifecycle and international trade. Source: OECD Trade Policy Paper, 2022, page 13



Recent OECD work identifies four separate phases in an AI system's lifecycle [7]:

1. **Design, data and modeling** include several activities, whose order may vary for different AI systems: Planning and design of the AI system involves articulating the system's concept and objectives, underlying assumptions, context and requirements, and potentially building a prototype.
2. **Verification and validation** involve executing and tuning models, with tests to assess performance across various dimensions and considerations.
3. **Deployment** into live production involves piloting, checking compatibility with legacy systems, ensuring regulatory compliance, managing organizational change and evaluating user experience.
4. **Operation and monitoring** of an AI system involve operating the AI system and continuously assessing its recommendations and impacts (both intended and unintended) in light of objectives and ethical considerations. This phase identifies problems and adjusts by reverting to other phases or, if necessary, retiring an AI system from production.

3. Pros and Cons of AI in International Trade.

According to International Trade Council, 2023, artificial intelligence can significantly help in the control of international trade shipments, especially in the case of border control of goods [16]. There are two main significant use cases for AI that can help trade. The first one is the opportunity to detect anomalies. One of the potential applications is the detection of anomalies. Detection of inaccurate data is done by analyzing the documents provided using neural networks, whether in manifests or customs declarations. Secondly, artificial intelligence can also be used to generate HS code suggestions by analyzing the description of the goods, the point of origin, destination and any other parameter that we want to function as a control parameter. This can help to avoid fraud and prevent delays due to bad HS classification [10]. The report, titled “*World Trade Report 2025: Making Trade and Artificial Intelligence Work Together for the Benefit of All*,” cites that AI applications contribute to productivity in the economy, enabling more companies to comply with complex regulations. “*Goods that enable AI, such as semiconductors and intermediate inputs*,” play a key role in global trade, as the trade volume of these products reached \$2.3 trillion in 2023.

In the following are listed the **pros and cons of AI in International Trade**.

- *Improved efficiency in supply chain management*: By analyzing real-time data, AI systems can help businesses adapt to changing market conditions and adjust their operations accordingly. Additionally, AI-powered predictive analytics can help companies anticipate and mitigate supply chain disruptions, reducing the risk of bottlenecks and delays.
- *Enhanced decision-making through data analysis*: Artificial intelligence can further enhance decision-making by automating the analysis of vast amounts of data, identifying patterns and correlations that might not be immediately apparent to humans. As a result, businesses can respond to changes in the market quickly and effectively, giving them a competitive edge over their rivals.
- *Increased productivity and competitiveness*: One of the main benefits of implementing artificial intelligence in international trade is the potential for increased productivity and competitiveness. AI can effectively automate routine and time-consuming tasks, allowing employees to shift their focus towards more value-added tasks. In addition, AI can provide real-time data analysis and insights, which can inform decision-making and optimize supply chain logistics.
- *Reduction in labor costs*: As AI-powered machines become increasingly sophisticated and intelligent, they are capable of performing more complex tasks and operations that were previously the exclusive domain of human workers. This significantly reduces the amount of money that businesses need to invest in labor, as machines are far more cost-effective than human employees in the long run.

Despite the potential benefits of AI in international trade, there are also several **concerns and challenges** that need to be addressed.

Among all, the following need to be mentioned:

- *Job displacement due to automation*: The implementation of automation in the workforce will lead to the creation of new jobs, such as technicians to maintain and monitor the automated systems. Additionally, the use of AI in industries such as healthcare and transportation will create new roles for individuals to work alongside the technology, such as data analysts and programmers.

- *Dependence on technology:* AI reduces the need for labor through the integration of machines and algorithms into the work process. This dependence on technology may lead to a loss of critical thinking and analytical skills, as well as a lack of human interaction or empathy. Individuals are getting too reliant on technology, leading to dependency, which could exacerbate problems such as, breach of privacy, and giving up personal information.
- *Data privacy and security concerns:* With sensitive information such as personal data, financial records, and trade secrets being processed through AI systems, the risk of data breaches and cyber-attacks becomes more significant. In addition, the possibility of bias and discrimination in AI decision-making also poses a threat to privacy and security.
- *Potential for monopolies and unfair competition:* As AI-powered technologies become more sophisticated and dominant in different industry sectors; they may create barriers to entry, prevent new players from entering the markets, and limit the ability of existing firms to compete. This is particularly true in industries where the cost of entry is high, and the economies of scale play an essential role in driving down prices and improving quality.

4. Albania's Foreign Trade in the Recent Years

Albania's foreign trade represents 82% of its GDP and is primarily conducted with Europe (World Bank, latest data available).

According to data by INSTAT, in 2024, the country's main exports were textile and footwear (28.7%), minerals, fuels, electricity (21.4%), construction materials and metals (18.9%), food, beverages, tobacco (12.6%), and machinery, equipment and spare parts (8.9%); whereas imports were led by machinery, equipment and spare parts (26.7%), food, beverages, tobacco (17.5%), construction materials and metals (13.4%), chemical and plastic products (13.0%), minerals, fuels, electricity (10.4%), and textile and footwear (9.7%).

Albania's total Exports in 2024 were valued at US\$4.00 Billion, according to the United Nations COMTRADE database on international trade. Albania's main export partners were: Italy, Serbia and Greece. The top three export commodities were: Mineral fuels, oils, distillation products; Footwear, gaiters and the like, and Articles of apparel, not knit or crocheted. Total Imports were valued at US\$9.60 Billion.

In 2024, Albania had a trade deficit of US\$5.60 Billion. In terms of countries, in 2024, the main export partners were Italy (43.7%), Kosovo (9.9%), Greece (6.3%), Spain (3.5%), and North Macedonia (3.2%), with imports coming chiefly from Italy (21.2%), followed by China (10.9%), Turkey (10.8%), Greece (7.6%), Germany (7.2%).

In 2006, Albania signed the Stabilization and Association Agreement (SAA) with the EU, ratified in 2009, which liberalized trade by reducing duties and non-tariff restrictions on agricultural and industrial goods. The country is also a member of the multilateral Central European Free Trade Agreement (CEFTA) and has signed several free trade agreements.

Table 1. Albania's Foreign Trade 2020-2024

Foreign Trade Values	2020	2021	2022	2023	2024
Imports of Goods (million USD)	5,570	7,718	8,399	8,694	9,612
Exports of Goods (million USD)	2,506	3,559	4,309	4,374	4,000
Imports of Services (million USD)	1,335	1,918	2,474	3,411	3,758
Exports of Services (million USD)	2,532	4,055	4,982	6,992	7,962

Source: World Trade Organization (WTO)

Albania's trade balance is structurally in deficit, mainly because exports are neither sufficiently diversified nor competitive in terms of price, and because of the country's narrow production base. In 2023, merchandise exports were stable y-o-y at USD 4.3 billion, while imports increased by 2.5%, reaching USD 8.6 billion. However, the country is a net exporter of commercial services, which amounted to USD 7.2 billion against USD 3.4 billion in imports (+43.3% and +38.3% respectively - data from WTO). According to the World Bank, the country's trade deficit stood at 5.2% of its GDP, narrowing from 10.3% one year earlier.

Data from the Institute of Statistics indicates that Albania's trade deficit for goods increased by 20.7% on the year to USD 5.5 billion in 2024, as imports grew 2.5% against a 15.3% decline in exports.

Table 2. Top 5 export countries. Source: [17]

Main Customers (% of Exports)	2024
Italy	43.7%
Serbia	12.1%
Greece	6.3%
Germany	5.9%
Spain	3.5%
Other Countries	28.5%

Table 3. Top 5 import countries. Source: [17]

Main Suppliers (% of Imports)	2024
Italy	21.2%
China	10.9%
Turkey	10.8%
Greece	7.6%
Germany	7.2%
Other Countries	42.3%

If we take a look at Albania's export and import base, (table 4 and 5) it can be seen that the export base consists mainly of traditional industries like textiles, minerals, and agriculture, does not currently allow for a strong profit from Artificial Intelligence (AI) due to a lack of domestic AI strategy, low investment in R&D, and a "brain drain" of tech graduates.

Table 4. Top 5 exported products of 2024 Source: [17]

4.0 bn USD of products exported in 2024	
Parts of footwear, incl. uppers whether or not	6.7%
Men's or boys' suits, ensembles, jackets, blazers	4.9%
Footwear with outer soles of rubber, plastics	4.0%
Insulated "incl. enameled or anodized" wire	3.5%
Bars and rods, of iron or non-alloy steel, not	2.3%
Other Products	78.6%

Table 5. Top 5 imported products of 2024. Source: [17]

9.6 bn USD of products imported in 2024	
Motor cars and other motor vehicles principally	7.4%
Petroleum oils and oils obtained from bituminous	5.9%
Medicaments consisting of mixed or unmixed	2.7%
Bars and rods, of iron or non-alloy steel, not	1.7%
Electrical Energy	1.4%
Other Products	80.9%

5. Conclusions and Recommendations

The impact of AI on international trade is vast and still continuous. Developments based on block chain technology and artificial intelligence can be used to make international trade easy and accessible to all types of organizations and actors involved in the supply chain, automating processes and ensuring the security and traceability of goods. This process could reduce the time spent on each file by about 80 per cent by enabling the pre-visualization of the documentation associated with the operation, reducing errors and avoiding the transport physical documentation.

Artificial intelligence has a great potential to reduce trade costs and increase productivity, as well as create new routes for manufacturing and service exports. Despite the potential benefits of AI in international trade, there are also several concerns and challenges that need to be addressed. Among all it can be mentioned job displacement due to automation, dependence on technology, data privacy and security concerns, potential for monopolies and unfair competition.

However, for a low-income country like Albania, concrete investments and comprehensive policies are needed, so that artificial intelligence can go towards reducing inequalities in the country. The export base of Albania remains very low and mainly based on exporting low-value-added products, such as primary and agricultural products or clothing and footwear for the production of which the raw material is also provided through imports and these products are destined for export, but in the meantime only the free arm of the labor force in Albania is used for their production.

Finally it can be said that the creation of a competitive domestic environment is complementary and goes beyond trade reform and the elimination of barriers to investment. It is not enough to adopt an externally oriented policy, which aims at the gradual elimination of quantitative restrictions through tariffs, but trade policy must operate within the framework of efficient macroeconomic policies. For this, there is a need for policymakers to improve the supply side of the Albanian economy by placing emphasis on rationalizing investment rules, institutional reforms, removing price controls and adopting cost-minimizing technology so that the country can benefit from global and regional integration and also AI.

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ARTIFICIAL INTELLIGENCE AND THE TRANSFORMATION OF HUMAN RESOURCE MANAGEMENT IN EDUCATION: TOWARDS A HUMAN- TECHNOLOGY MODEL

**Candidate Albana ALLUSHAJ PhD., MSc. Semi GOLEMI, Krista MOUSTA –
Student**

*"Eqrem Çabej" University of Gjirokastra, Albania
Corresponding author - Albana Allushaj: aallushaj@uogj.edu.al*

Abstract

In the reality where artificial intelligence (AI) is revolutionizing the way we think, learn and work, Human Resource Management in education is experiencing one of the most profound transformations, challenging traditional models of organization and management. The purpose of the paper is to analyze the way in which artificial intelligence affects the transformation of human resource management practices in education and the construction of a new model of human-technology interaction. The study is based on the theoretical-analytical method and the reflective approach, based on contemporary literature and international documents of educational policies, but at the same time also includes an empirical component, through the development of questionnaires with students and teachers of Master's programs in the field of teaching. It examines the impact of artificial intelligence on the processes of recruitment, professional development, performance evaluation and motivation of teaching staff. At the same time, the study also places the analysis in the context of contemporary developments in Albanian education where new digitalization strategies, training for digital competencies of teachers and reforms in human resource management in public educational institutions are being implemented. The analysis emphasizes that effective human resource management in the era of artificial intelligence requires a balance between technological efficiency and human well-being, emphasizing the construction of a new model of human-technology interaction that responds to the needs of the global and Albanian education system. The results show that, although artificial intelligence increases efficiency through automation and data analysis, the human factor remains essential for maintaining ethics, creativity and well-being at work. The paper argues that human resource management in education should evolve towards a human-technological model, where technology serves as a tool for empowerment and innovation rather than replacing humans. Only through this balance can education embrace the digital revolution without losing its human and emancipatory dimension.

Keywords: Artificial Intelligence, Human Resource Management, Education, Human Technology Interaction, Ethics and Wellbeing Teacher Professional Development.

Introduction

Artificial Intelligence (AI) is reshaping the way organizations work and make decisions, and in education its impact goes beyond classroom tools. AI is increasingly intertwined with core

Human Resource Management (HRM) functions, such as recruitment and selection, professional development, performance support, and teacher motivation and retention. While AI can improve efficiency and provide data-driven support, it also raises risks related to fairness, transparency, and professional identity – issues that are particularly sensitive in education because HR decisions affect career progression and access to training.

This study examines how AI is transforming HR practices in education and what kind of human-technology model is needed to ensure that AI strengthens (rather than undermines) fairness, professional identity, and well-being. To connect global discussions to the Albanian context, we combine the literature with survey evidence from master's students/teachers, focusing on perceptions of AI, readiness and training needs, and the supporting role of HR structures (DAR/ZA).

Literature Review

Research suggests that AI can support HRM through evidence-based feedback, automation of repetitive tasks, and more personalized professional development, potentially increasing engagement and retention [1]. However, effective HR-AI collaboration requires explainability, human oversight, and safeguards in high-risk contexts, as perceptions of fairness and threats to professional identity can reduce adoption [2]. In education, adoption is strongly shaped by teachers' perceptions, familiarity, and perceived usefulness; therefore, HRM should lead capacity building and change management—not just introduce tools [3]

Studies highlight the need to redesign teacher professional development to include AI literacy, practical experience, and ethical awareness, while acknowledging parallel concerns about privacy, bias, and inequality that require governance [4]

Our survey results reflect these patterns: respondents show high motivation to learn about AI and expect it to impact their profession, but they also report a strong need for practical training and emphasize that AI should “support not replace” teachers skills. In addition, patterns of contact with Human Resources offices (DAR/ZVA) suggest that support is often “as needed,” reinforcing the need for more effective HR communication, training planning, and ongoing support. Together, the literature and findings point to a human-centered HRM-AI model, where AI improves decision-making support and professional learning, while HR structures ensure fairness, transparency, identity protection, and well-being.

Purpose of the Study and Research Questions

Building on the identified gap, this study aims to examine how AI is perceived to transform HRM practices in education and what this implies for a human-technology interaction model that balances efficiency, fairness, professional identity, and well-being.

The Study Is Guided by the Following Research Questions

RQ1. What are master's students/teachers' perceptions of AI's role in transforming HRM functions in education (e.g., recruitment/selection, professional development, feedback/performance support, and motivation)?

RQ2. To what extent do participants feel prepared to use AI, and what training needs do they report for AI use in teaching/learning and HRM-related tasks?

RQ3. How do participants perceive the role of HR offices (DAR/ZA) in supporting professional development and AI readiness, and how frequently do they interact with these structures?

RQ4. What concerns emerge regarding professional identity and well-being, and what do these imply for designing a human-technology interaction model in educational HRM?

Yes, below I have re-conceptualized the methodology by including the abbreviations you requested (ZA, DAR, HR, HRM) and making the text more coherent, academic and fluent.

Research Methodology

This study uses a combined theoretical-analytical, reflective and empirical approach, using a descriptive survey model. Data were collected through a structured questionnaire administered to master's students and teaching staff in the Department of Education at "Eqrem Çabej" University, Gjirokastrë.

Participants

A total of 143 respondents completed the questionnaire. Minor variations in the number of responses at the item level occurred due to non-response and platform rounding. Participants represent a diverse group of education professionals actively engaged in or familiar with Human Resources (HR) processes within Albanian pre-university institutions.

Instrument

The final questionnaire consisted of 14 questions, grouped into the following sections:

1. General demographic and professional information
2. Awareness and perceptions of AI in relation to Human Resource Management (HRM) in education, measured on a 1–3 Likert scale (1 = Disagree; 2 = Agree; 3 = Strongly Agree)
3. AI preparation and training needs (Likert 1–3)
4. Self-use of AI for professional development and HR-related tasks
5. Interaction with HR offices, specifically the Regional Education Directorate (DAR) Office of Education (ZA)
6. An open-ended question, focused on suggestions for improving the integration of AI in HR

Development and Calibration of the Instrument (Pilot Testing)

The initial version of the questionnaire included "18 questions", designed in accordance with the conceptual framework of the study on AI-supported HRM functions in educational institutions. To ensure validity, clarity and contextual accuracy, the instrument was pilot tested with 10 teachers. Feedback indicated issues related to the formulation of questions, repetition of questions and the need for closer alignment with the structure and practices of the Human Resources offices in Albania (ZA, DAR). As a result, the questionnaire was improved and reduced from 18 to 14 more concise, relevant and understandable questions.

Data Collection (Google Forms)

Data were collected online using Google Forms. The questionnaire link was distributed to Master's students/teachers, and responses were automatically recorded by the platform for subsequent descriptive analysis (frequencies and percentages). The instrument was administered via: <https://forms.gle/8S5vr83ze8EDkWgC8>

Analysis.

Quantitative data were analyzed using descriptive statistics (frequencies and percentages). Open-ended responses were synthesized thematically to identify recurring priorities for HR support and AI readiness.

Results

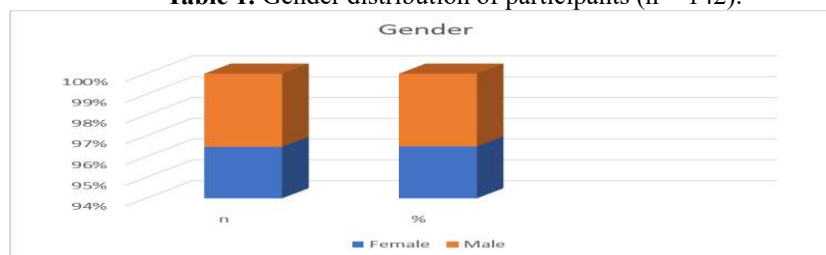
Section A — General Information

Tables 1–8 summarize the demographic and professional profile of participants. Overall, the sample is predominantly female and composed largely of experienced educators, which is consistent with patterns of feminization in teaching and a strong link between postgraduate study and professional development.

Gender Distribution of Participants

For question 1 (Gender), a total of 143 students/teachers completed the questionnaire, but 142 people answered this question (1 answer missing), of which gender, 96.5% were female and 3.5% male. This distribution shows a clear dominance of female participation in the study sample (Master's level students/teachers in education), reflecting the tendency for the teaching education and profession to have a higher representation of women. (*Table 1*)

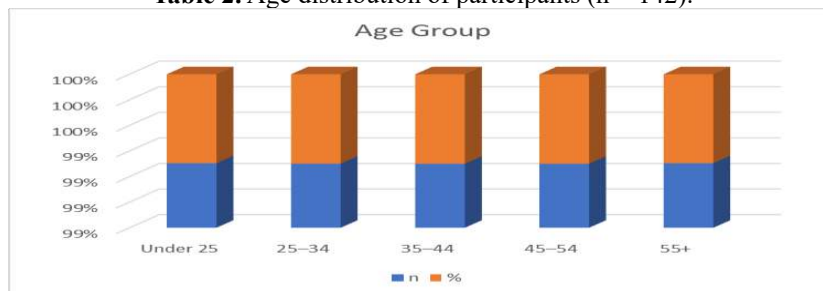
Table 1. Gender distribution of participants (n = 142).



Age Distribution of Participants

Regarding the age of the participants (Question 2), out of a total of 143 participants, 142 students/teachers answered this question (1 person did not answer). The results show that the highest percentage is made up of the 45-54 age group with 47.2%, making this the dominant category of the sample. In second place is the 35-44 age group with 30.3%, while 19.7% of the participants belong to the 25-34 age group. The participation of younger ages is minimal: only 0.7% are under 25 years old (1 person), while the age group over 55 years old is represented by 2.1% (3 people). This distribution shows that the sample is mainly composed of mature professionals, with a very low presence of very young participants (Table 2)

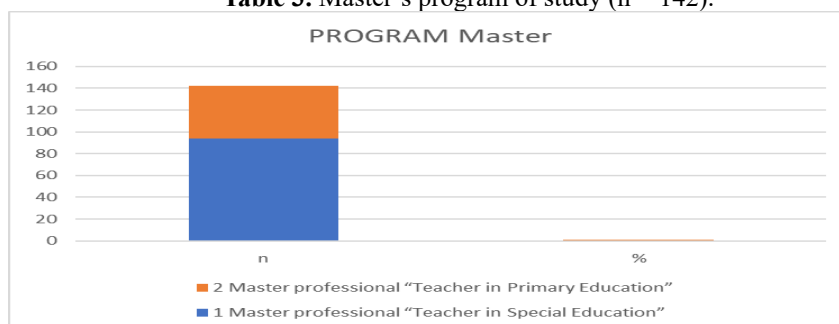
Table 2. Age distribution of participants (n = 142).



Master's Program of Study

Regarding the Master's program that the participants are pursuing (Question 3), out of 143 participants in total, 142 people answered this question (1 did not answer). The results show that 94 participants, or 66.5%, are pursuing the professional Master's "Teacher in Special Education", while 48 participants, or 33.5%, are enrolled in the professional Master's "Teacher in Primary Education". This distribution reflects a clear trend towards choosing Special Education, suggesting an increased interest in professional profiling and more specialized preparation to work with students with special needs and in inclusive contexts. (Table 3).

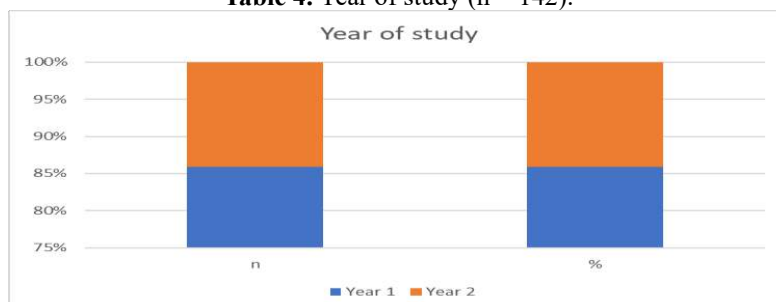
Table 3. Master's program of study (n = 142).



Year of Study

Regarding the year of study (Question 4), 142 people out of 143 participants in total answered this question (1 person did not answer). The results show that the vast majority of students/teachers, 122 participants or 85.9%, are in the first year of Master studies, while only 20 participants or 14.1% are enrolled in the second year. This distribution suggests that the sample is mainly composed of students who are in the initial phase of specialization at Master's level in teaching. (Table 4).

Table 4. Year of study (n = 142).



Teaching Experience

Regarding teaching experience (Question 5), out of a total of 143 participants, 141 people answered this question (2 did not answer). The results show that the majority of the sample has considerable work experience: 51 participants (36.2%) declare over 20 years of experience, while 33 people (23.4%) have 10–20 years of work. A significant segment is also represented by teachers with shorter experience: 29 participants (20.6%) report 2–5 years of experience and 16 people (11.3%) have 5–10 years of work. Finally, 12 participants declare up to 1 year of experience, which accounts for about 8.5% of those who responded. (Table5).

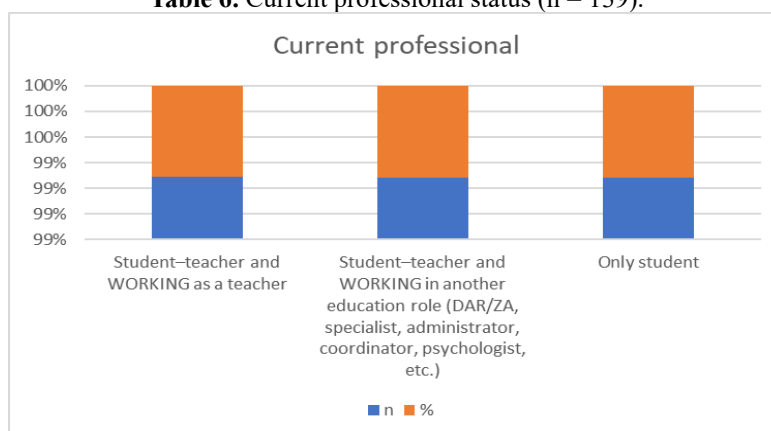
Table 5. Teaching experience (n = 141).



Current Professional Status

Regarding current professional status (Question 6), out of 143 participants in total, 139 people answered this question (4 did not answer). The results show that the majority of the sample, 120 participants or 86.9%, are student teachers and simultaneously work as teachers. Meanwhile, 10 participants (7.2%) declare that they hold other educational positions (e.g., in DAR/ZA, specialist, administrator, coordinator, school psychologist, etc.), while 9 people or 6.5% are only students without current professional engagement. This distribution shows that the main group of participants is made up of active teachers, which suggests that they are investing directly in their academic training for increased professional capacity and career development. (Table 6).

Table 6. Current professional status (n = 139).

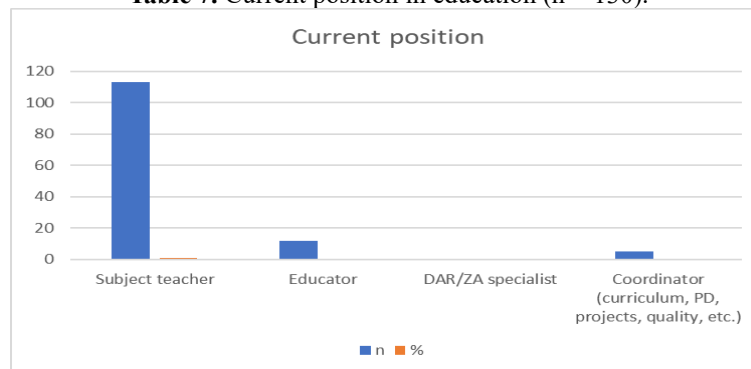


Current Position in Education

Out of 143 participants, 130 answered this question (13 missing). Most respondents are employed as subject teachers (n=113; 86.9%), followed by educators (n=12; 9.2%). Only a small group reported coordination roles (n=5; 3.8%) related to curriculum, professional development, or projects, and no participant identified as a DAR/ZA specialist (Table 7).

The lack of DAR/ZA specialists suggests that the findings reflect mainly teachers' experiences of HR support, reinforcing the need for ZA/DAR to strengthen AI-related training, guidance, and communication channels.

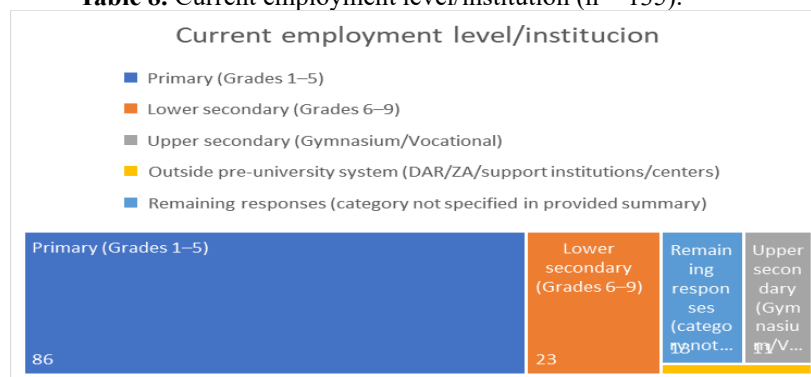
Table 7. Current position in education (n = 130).



Current Employment Level/institution

Of the 143 participants, 135 answered this question (8 missing). The majority of respondents work in "primary education (grades 1–5)" (n=86; 63.7%), followed by "lower secondary school (grades 6–9)" (n=23; 17%) and "upper secondary school (gymnasium/vocational)" (n=11; 8.1%). A small group reported working in "institutions outside the pre-university system", such as DAR/ZA or support centers (n=2; 1.5%). Regarding "Human Resources and AI in Education", this distribution shows that the findings mainly reflect the reality of "basic education", especially the primary cycle - where HRM plays a central role in recruiting. The participation of respondents linked to ZA/DAR support structures is also important, as these institutions are key stakeholders for HRM policies and can help institutionalize AI-led professional development through clearer guidance, communication and training pathways.

Table 8. Current employment level/institution (n = 135).



Results in Line with Research Questions

To improve interpretability, the descriptive results are summarized below in line with the study's research questions (RQ1–RQ4).

RQ1: Perceptions of AI across HRM functions in education

Responses indicate generally positive perceptions of AI as a driver of HRM transformation in education. Participants report strong motivation to learn more about AI in education and HRM and anticipate that AI will impact their profession (Table 9, E1–E2). Perceived value is strongest for professional development and performance support: most participants agree that AI can provide personalized training recommendations and support the continuous improvement of professional competencies (Table 9, E5–E6). At the same time, perceptions about AI in selection processes are more cautious, suggesting that fairness and transparency remain key acceptance conditions for AI-supported personnel decisions.

Results are summarized in Table 9

Awareness and understanding of AI in education & HRM (Likert 1–3)

1 = Strongly disagree; 2 = Agree; 3 = Strongly agree.

E 9.1 Out of 143 participants, 140 responded to item E9.1. The vast majority (96.4%) agreed or strongly agreed that they are motivated to learn more about AI in education and HRM (54.3% strongly agree; 42.1% agree). From an HRM perspective, this indicates strong readiness for capacity building: schools and ZVA/DAR can leverage this "ready human capital" by offering structured, practice-oriented training, clear guidance, and continuous professional development programs that position AI as a tool to strengthen-rather than replace-the teacher's role.

E 9.2 "The question about "awareness and understanding of AI", out of 143 participants, 137 people responded, where 32 students (23.4%) expressed "strongly disagree", 65 (47.4%) "agree", while 41 (29.9%) "strongly agree". In summary, the result shows a "generally positive trend" towards AI (about 77.3%, agree or strongly agree), which means that most participants have a satisfactory level of awareness and understanding of the role of AI in education and HRM. However, the presence of a significant group that disagrees (23.4%) indicates that there are still knowledge gaps and uncertainties, which need to be addressed by human resource management (school/ZA/DAR) through "basic AI training", clear guidelines and practical support. This is important because without a common understanding and minimum competencies, the integration of AI remains partial and risks creating inequalities in teachers' professional development.

E 9.3: "AI can improve fairness and objectivity in teacher/staff selection", out of 143 participants in total, 138 responded (5 did not respond). According to the Likert scale 1–3, 32 participants (23.2%) expressed "Strongly Disagree", 65 (47.1%) "Agree" and 41 (29.7%) "Strongly Disagree". Thus, 76.8% of respondents agree or strongly agree that AI can contribute to increasing fairness and objectivity in selection processes. However, the fact that almost a quarter (23.2%) strongly disagree also signals an important reservation which, in the context of HRM, is often related to concerns about algorithmic bias, lack of transparency in decision-making or the fear that the process may become "mechanical". This means that, even when AI is considered useful, its integration into selection requires clear rules, transparency, human oversight, and ethical criteria, so that the technology serves as a support for decision-making, not a substitute for professional responsibility.

E 9.4: “IA systems can help identify candidates who are better suited to the school’s needs”, out of a total of 143 participants, 140 responded (3 did not respond). According to the Likert scale 1–3, 23 participants (16.4%) expressed “Strongly disagree”, 78 (55.7%) “Agree” and 39 (27.9%) “Strongly agree”. In total, 83.6% agreed or strongly agreed with this statement. However, the presence of a significant group (16.4% “strongly disagree”) suggests that there is scepticism about the reliability or fairness of these systems. In HRM terms, this makes it necessary: clear professional criteria, data verification, transparency in the selection logic and human oversight, so that AI serves as a support for HRM and not as a factor that increases uncertainty, bias or unexplained decision-making.

E 9.5: “AI can provide personalized training recommendations”, out of 143 participants, 138 responded (5 did not respond). According to the Likert scale 1–3, 10 participants (7.2%) expressed “Strongly disagree”, 79 (57.2%) “Agree” and 49 (35.5%) “Strongly agree”. In total, 92.8% agreed or strongly agreed, which indicates a very high support for the use of AI in personalizing training. In the human resources (HRM) function, this result is directly related to one of the most important functions: professional development and in-service training. A relatively small percentage (7.2%) that “strongly disagree” suggests that for some participants, dilemmas remain about how AI “knows” what training is needed, or about data privacy. Therefore, for HRM it is important that personalization with AI is accompanied by clear professional criteria, privacy protection and transparency in recommendations, so that teacher trust is increased and use is sustainable.

E 9.6: “IA can help teachers continuously improve professional competences”, out of 143 participants in total, 140 responded (3 did not respond). According to the Likert scale 1-3, 7 participants (5.0%) expressed “Strongly disagree”, 79 (56.4%) “Agree” and 54 (38.6%) “Strongly agree”. In total, 95.0% agreed or strongly agreed, which indicates a strong consensus on the role of IA in the continuous improvement of professional competences. The fact that only 5% “strongly disagree” shows that resistance is low, but still present. Therefore, HRM should ensure that this support is accompanied by practical training, clear guidelines and ethical standards, so that the improvement of competences is sustainable and equitable for all teachers.

E 9.7: “IA-generated feedback can be useful for teachers”), out of 143 participants, 139 responded (4 did not respond). On a 1-3 Likert scale, 16 participants (11.5%) responded “Strongly disagree”, 78 (56.1%) “Agree” and 45 (32.4%) “Strongly agree”. In total, 88.5% agreed or strongly agreed that AI-generated feedback can be useful. In the human resources function (HRM), this result is directly related to performance appraisal and professional development. The fact that 11.5% “strongly disagree” suggests that some participants may have reservations about the reliability, contextualization or fairness of feedback produced by IA.

E 9.8: “Integration of IA can increase teachers’ professional motivation”, out of 143 participants, 138 responded (5 did not respond). According to the Likert scale 1-3, 9 participants (6.5%) expressed “Strongly disagree”, 75 (54.3%) “Agree” and 54 (39.1%) “Strongly agree”. In total, 93.5% agreed or strongly agreed, which indicates a high expectation that IA can positively affect professional motivation. For HRM (school and ZA/DAR), this means that the integration of IA can be used not only as a technological modernization, but also as a strategy for improving the working climate and increasing motivation through daily professional support. Therefore, the role of HRM is to provide appropriate training, equal access to tools, clear instructions and ongoing support, so that IA is seen as an empowering tool and not as a source of additional stress or pressure.

E 9.9: “I am concerned that IA may negatively impact the professional identity of teachers”, out of 143 participants in total, 140 responded (3 did not respond). According to the Likert scale 1–3, 61 participants (43.6%) expressed “Strongly disagree”, 50 (35.7%) “Agree” and 29

(20.7%) “Strongly agree”. In total, 56.4% agree or strongly agree that they have this concern, while 43.6% do not share this concern. In the function of human resources (HRM), this is one of the most critical results, because it is related to professional well-being, sense of role and resistance to change.

E 9.10: “The balance between technology and human well-being is essential in schools”, out of 143 participants in total, 140 responded (3 did not respond). According to the Likert scale 1-3, 8 participants (5.7%) expressed “Strongly disagree”, 74 (52.9%) “Agree” and 58 (41.4%) “Strongly agree”. In total, 94.3% agreed or strongly agreed, indicating a very strong consensus on the importance of the technology-well-being balance. So, this result establishes “human well-being” as the guiding criterion for any HRM decision-making regarding AI: technology should bring about improved working conditions and professional development, not just administrative efficiency

E 9.11: “AI should enhance, not replace, teacher skills”), out of 143 participants in total, 141 responded (2 did not respond). According to the Likert scale 1–3, 11 participants (7.8%) expressed “Strongly disagree”, 41 (29.1%) “Agree” and 89 (63.1%) “Strongly agree”. In total, 92.2% agreed or strongly agreed, indicating a very clear position that AI should have a supportive role and not a replacement. For HRM (school/ZA/DAR), this means that any AI strategy must be built on: training that increases competencies, ethical standards, human supervision, and clear communication that reduces fear of replacement—because this is directly linked to motivation, professional identity, and readiness for technology adoption.

Results Aligned with Research Questions

To improve interpretability, the descriptive results are summarized below in alignment with the study's research questions (RQ1–RQ4).

RQ1: Perceptions of AI across HRM functions in education

Responses indicate overall positive perceptions of AI as a driver of HRM transformation in education. Participants report strong motivation to learn more about AI in education and HRM and anticipate that AI will influence their profession .

(Table 9, E1–E2). The perceived value is strongest for professional development and performance support: most participants agree that AI can provide personalized training recommendations and support continuous improvement of professional competencies (Table 9, E5–E6). At the same time, perceptions around AI in selection processes are more cautious, suggesting that fairness and transparency remain key acceptance conditions for AI-supported staffing.

Table 9. AI awareness and HRM-related perceptions (Likert 1–3; item-level n varies).

Item	1=Not agree n (%)	2=Agree n (%)	3=Fully agree n (%)	n
E9.1. Motivated to learn more about AI in education and HRM	5 (3.6%)	59 (42.1%)	76 (54.3%)	140
E9.2. AI will directly affect my profession	13 (9.3%)	72 (51.4%)	55 (39.3%)	140
E9.3. AI can improve fairness/objectivity in teacher/staff selection	32 (23.2%)	65 (47.1%)	41 (29.7%)	138
E9.4. AI systems can help identify candidates who match school needs	23 (16.4%)	78 (55.7%)	39 (27.9%)	140

Item	1=Not agree n (%)	2=Agree n (%)	3=Fully agree n (%)	n
E9.5. AI can provide personalized training recommendations	10 (7.2%)	79 (57.2%)	49 (35.5%)	138
E9.6. AI can help teachers continuously improve professional competencies	7 (5.0%)	79 (56.4%)	54 (38.6%)	140
E9.7. AI-generated feedback can be useful for teachers	16 (11.5%)	78 (56.1%)	45 (32.4%)	139
E9.8. AI integration can increase teachers' professional motivation	9 (6.5%)	75 (54.3%)	54 (39.1%)	138
E9.9. Concern: AI may negatively affect teachers' professional identity	61 (43.6%)	50 (35.7%)	29 (20.7%)	140
E9.10. Balance between technology and human well-being is essential in schools	8 (5.7%)	74 (52.9%)	58 (41.4%)	140
E9.11. AI should reinforce, not replace, teacher abilities	11 (7.8%)	41 (29.1%)	89 (63.1%)	141

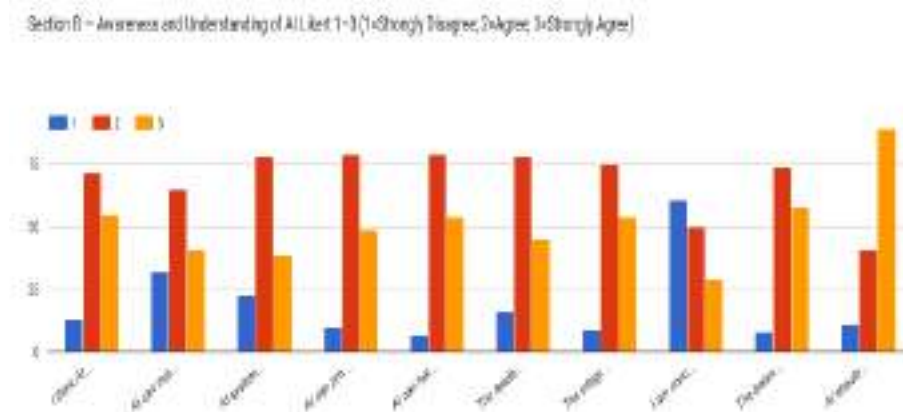


Table 9. (E1, E2, E3, E4, E5, E6, E7, E8, E9, E10, E11). AI awareness and HRM-related perceptions (Likert 1–3; item-level n varies)

Section F — Professional preparation and training for AI

RQ2: Preparedness and training needs for AI use (teaching/learning and HRM)

Perceived preparedness is moderate, while demand for practical training is high (Table 10). Although many respondents select at least “agree” that they feel prepared to use AI in work tasks (F1), a very large majority report the need for more practical, hands-on training to use AI in learning, teaching, and HRM-related tasks (F3). This gap between openness and readiness is central for educational HRM, because it signals a capacity-building and change-management need rather than simple resistance to innovation.

F10.1: “I feel prepared to use AI in my work tasks”), out of 143 participants in total, 141 responded (2 did not respond). According to the Likert scale 1–3, 24 participants (17.0%) expressed “Strongly disagree”, 83 (58.9%) “Agree” and 34 (24.1%) “Strongly agree”. In total, 83.0% agree or strongly agree that they feel prepared to use AI in their work tasks. In the human resources (HRM) function, this result is very significant because “preparedness” is a practical indicator of the staff’s capacity to adopt AI in a sustainable manner. Although the majority express themselves positively, the fact that only 24.1% strongly agree and 17.0% strongly

disagree suggests that there is a gap between motivation (high in the awareness section) and practical certainty for use.

F10.2: “The Master’s program has equipped me with sufficient knowledge about IA”), out of 143 participants in total, 143 responded (no gaps). According to the Likert scale 1–3, 13 participants (9.1%) expressed “Strongly disagree”, 84 (58.7%) “Agree” and 46 (32.2%) “Strongly agree”. In total, 90.9% agree or strongly agree that the Master’s program has equipped them with sufficient knowledge about IA. In terms of human resources (HRM), this result is important because it shows the role of university education (Master’s) as a “supply link” of the education system with qualified staff for digital transformation. However, with only 32.2% strongly agreeing, while the majority “agree”, this suggests that the knowledge may be more general than in-depth/practical.

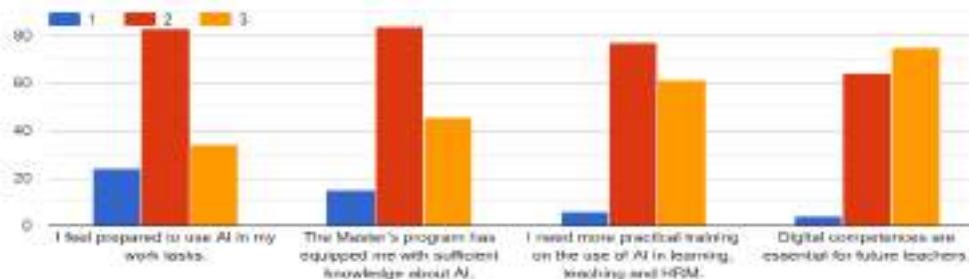
F10.3: “I need more practical training on the use of AI in learning, teaching and HRM”, out of 143 participants in total, 141 responded (2 did not respond). According to the Likert scale 1–3, 6 participants (4.3%) expressed “Strongly disagree”, 76 (54.6%) “Agree” and 61 (43.3%) “Strongly agree”. In total, 95.7% agreed or strongly agreed, indicating a very strong demand for more practical training. In the focus of human resources (HRM), this is one of the most important results, because it clearly states that the implementation of AI in education cannot rely only on theoretical knowledge: staff require operational training, linked to real work tasks.

F 10.4: “Digital competences are essential for future teachers”, out of 143 participants in total, 143 responded (no omissions). According to the Likert scale 1–3, 4 participants (2.8%) expressed “Strongly disagree”, 64 (44.8%) “Agree” and 75 (52.4%) “Strongly agree”. In total, 97.2% agreed or strongly agreed, reflecting a very broad consensus on the importance of digital competences. In the context of human resources (HRM) and AI in education, this result shows that participants see digital competence as a professional standard and not as an additional skill. (Table 10)

Table 10. Preparation and professional training for AI (Likert 1–3; item-level n varies).

Item	1=Not agree n (%)	2=Agree n (%)	3=Fully agree n (%)	n
F1. I feel prepared to use AI in work tasks	24 (17.0%)	83 (58.9%)	34 (24.1%)	141
F2. The Master program provided sufficient AI knowledge	13 (9.1%)	84 (58.7%)	46 (32.2%)	143
F3. I need more practical training to use AI in learning/teaching and HRM	6 (4.2%)	76 (53.5%)	61 (42.4%)	143
F4. Digital competences are essential for future teachers	4 (2.8%)	64 (44.8%)	75 (52.4%)	143

Section F – Professional Preparation and Training for AI 1. I feel prepared to use AI in my work tasks. Likert 1–3 (1=Strongly Disagree;2=Agree;3=Strongly Agree)



Self-use of AI for Professional Development

Self-reported AI use for professional development suggests that adoption is present but not yet universal, reinforcing the need for structured HR-supported training pathways.

Q11: Regarding Self-use of IA for professional development, out of 143 participants in total, 140 people responded to this section (3 did not respond). The responses show that 52 professional Master students (37.1%) declare that they use IA tools for their professional growth as teachers. Meanwhile, 46 participants (32.9%) state that AI helps them identify areas where they need to improve professionally, while 42 participants (30%) report that the use of IA has increased their ability to reflect on their performance as teachers. In function of the topic Human Resources (HRM) and AI in education, these data are very significant because they show that IA is being perceived not only as a technological tool, but as an instrument for professional self-development that is, an “internal mechanism” for increasing human capacities.

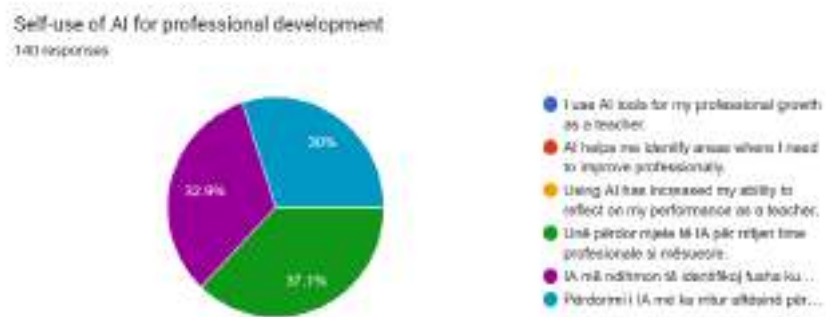


Table 11. Self-use of AI for professional development (n = 140).

Self-use of AI for professional development	n	%
Q11.1 Use AI tools for professional growth	52	37.1%
Q11.2 AI helps identify areas for professional improvement	46	32.9%
Q11.3 AI increased my ability to reflect on my teaching performance	42	30.0%

RQ3: Role of HR structures (DAR/ZA) and interaction patterns

Results show generally positive evaluations of HR-office communication, yet contact patterns appear often reactive rather than continuous (Tables 12–13). Most respondents agree

that communication with HR offices is clear and structured (Table 12), but frequency data indicate that nearly half contact HR “when needed,” while a substantial share report very rare or no contact (Table 13). This pattern matters for AI readiness: without continuous HR–teacher interaction, professional development and change management often occur late, at the point of need, rather than as planned capacity building.

H1: “I have regular contact with the HRO at the institution where I work”), out of 143 participants in total, 125 people responded (18 did not respond). According to the Likert scale 1–3, 20 participants (16.0%) expressed “Strongly disagree”, 64 (51.2%) “Agree” and 41 (32.8%) “Strongly agree”. In total, 84.0% agree or strongly agree that they have regular contact with the HRO/DAR. The fact that 18 people did not answer this question suggests that part of the sample may not have a clear or direct relationship with these structures (e.g. they may be only students or in roles where interaction is rare). For HRM, this is a signal that, for AI implementation, HR communication and services need to be more accessible and structured, so that AI training and orientation reach all teachers equally

H2: Out of 143 participants in total, 129 people responded (14 did not respond). According to the Likert scale 1–3, 9 participants (7.0%) expressed “Strongly disagree”, 76 (58.9%) “Agree” and 44 (34.1%) “Strongly agree”. In total, 93.0% agreed or strongly agreed, which shows that the majority of participants perceive the communication with the ZA/DAR as clear and structured. In function of the topic Human Resources and AI in education, this result is a positive indicator of the organizational capacities of HRM, because the integration of AI necessarily requires regular and understandable communication: training instructions, procedures, ethical standards, ways of use and technical support. The number of non-responses (14 people) suggests that not all participants have equal experience of communicating with these structures.

H3: Of the 143 participants in total, 125 responded (18 did not respond). On a 1–3 Likert scale, 14 participants (11.2%) responded “Strongly disagree”, 67 (53.6%) “Agree” and 44 (35.2%) “Strongly agree”. In total, 88.8% agreed or strongly agreed, indicating that most participants use the ZA/DAR as a point of reference when they need professional information.

In view of the topic Human Resources and AI in Education, this result is essential because it directly links HRM to professional development: the ZA/DAR is perceived as the main source for guidance on qualifications and training. On the other hand, the presence of 11.2% who do not turn to HR (“strongly disagree”) and the number of non-responses (18 people) suggest that there are also segments that either do not have full access, or do not see HR as the first channel of support. For HRM, this implies the need to strengthen communication and service mechanisms, so that support for AI and professional development is more visible, faster and more equitable for all teachers.



Table 12. Interaction and communication with HR office (DAR/ZA) (Likert 1–3; item-level n varies).

Item	1=Not agree n (%)	2=Agree n (%)	3=Fully agree n (%)	n
H1. I have regular contacts with the HR office (DAR/ZVA) in my institution	20 (16.0%)	64 (51.2%)	41 (32.8%)	125
H2. Communication with the HR office is clear and structured	9 (7.0%)	76 (58.9%)	44 (34.1%)	129
H3. I contact the HR office when I need information on qualifications/training/documentation	14 (11.2%)	67 (53.6%)	44 (35.2%)	125

Table 12. Interaction and communication with HR office (DAR/ZA) (Likert 1–3; item-level n varies).

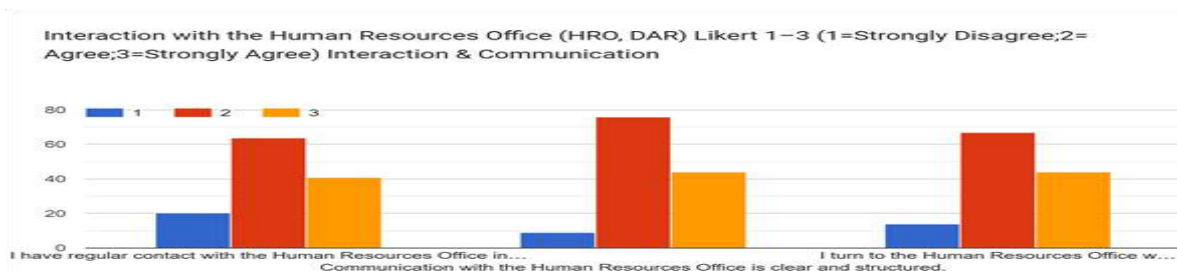
Results Are Summarized in Table 13

How often do you contact the Human Resources Office (HR)?”, out of 143 participants in total, 142 people responded (1 absent). The results show that 68 participants (47.9%) contact HR “as often as they need”, which suggests a communication model based on needs and concrete solutions. However, a significant portion, 41 participants (28.9%), report that they contact very rarely or never, while 24 people (16.9%) declare only 1–2 contacts per year. The highest frequency of communication is relatively rare: 8 participants (5.6%) contact 3–5 times per year, and only 1 participant (0.7%) reports over 5 contacts per year.

For the integration of IA, communication with HRM should not remain only “when the need arises”, because IA requires: regular orientation, planned training, guidelines on ethics and privacy, and implementation support. The fact that about a third of the participants contact rarely or not at all, and another part has only 1–2 contacts per year, suggests that HRM may not always succeed in creating a culture of continuous interaction with teachers a key element for professional development and for managing the change brought about by IA.

Table 13. Frequency of contact with HR office (DAR/ZA) (n = 142).

Frequency of contact with HR office (DAR/ZVA)	n	%
When I need it	68	47.9%
Very rarely / never	41	28.9%
1–2 times per year	24	16.9%
3–5 times per year	8	5.6%
More than 5 times per year	1	0.7%



RQ4: Professional identity, well-being, and implications for a human–technology model

Participants clearly endorse a human-centred stance: most agree that AI should reinforce rather than replace teachers’ abilities and that balancing technology with human well-being is essential (Table 9, E10–E11). At the same time, many report concerns that AI could negatively affect professional identity (Table 9, E9). This combination suggests “conditional acceptance”:

educators support AI if it augments professional work, but expect HR governance that protects identity, ethics, and well-being.

Open-ended responses (Q14): How can HR offices improve support for professional development and qualification? The open-ended responses converge on a clear direction for HR in the AI era: teachers expect more frequent and practical training (including AI training), systematic needs assessment, timely and transparent communication (including legal guidance), a stronger HR presence in schools, and improved infrastructure that enables digital practice. These themes support a human-technology model where HR structures function as facilitators of capacity building and ethical adoption.

Table 14. Thematic summary of proposals to improve HR support for teacher qualification and professional development (Q14).

Main topic (HRM + IA)	What participants are looking for (summary)	Sample answers (short verbatim quotes)
More frequent and practical training, especially for AI	More training, with concrete practices and real use of AI in teaching/HRM	"Let's do as much training as possible"; "More training on the use of AI."; "Professional development should be concrete and not fictitious"
Needs identification + strategic professional development planning	HR to assess real needs and build tailored programs; monitor progress	Identify training needs..."; "Strategic planning of professional development. Regular assessment of needs..."; "Conducting surveys regarding teacher needs"
Clearer communication, timely information, transparency	Regular information on training/qualifications/ documentation; legal and procedural guidance	"By sending them information from time to time..."; "I have to give as much information as possible when we need it."; "By informing them of the legal basis"
Support closer to school: meetings, listening, collaboration	HR should be more present in schools, frequent meetings, listen to problems	"She should meet with teachers more often"; "Looking at the problems more closely..."; "Be present at meetings in schools and listen to the needs..."
Infrastructure and technological tools (condition for AI)	Without devices/internet, AI cannot be implemented; classroom tools and a material base are required	"Providing technological tools in schools"; "creating conditions... (laptops, internet and interactive whiteboards...)"; "Based on additional materials for the learning process"
Accredited training + cooperation with training institutions	Quality courses, valid for credit; collaboration with institutions/ASCAP	"Online seminars that are valid for professional credits"; "Collaboration with training institutions to bring accredited courses..."
Standardization of procedures and documentation/career orientation	HR as a "guide" for professional documentation, career, qualifications database	"HR can serve as a guide for documentation..."; "Have a database... and constantly inform..."; "simplify bureaucratic procedures"
Motivation, protection of the teacher's image and well-being	Support for the teacher's role, fair motivation, no pressure, professional respect	With support and transparency"; "give more support to the teacher figure..."; "Balance between technology and well-being..."

Discussion

The results support the view that AI is perceived as a transformative driver for HRM in education-especially in professional development and feedback/performance support-while also highlighting clear conditions for trust and acceptance. This is consistent with IA-HRM arguments that AI can increase efficiency and enable evidence-based, more customized support, yet requires responsible governance.

In line with organization-design research, acceptance of HR-IA systems depends on explainability, appropriate safeguards for high-stakes decisions, and protection of professional identities [2]. The observed identity concerns in the survey emphasize that HRM must incorporate ethics and well-being safeguards (e.g., transparency, accountability, training on responsible use, and human oversight) when AI tools are introduced.

Finally, teacher readiness emerges as an HRM priority. The high reported need for practical training indicates that a positive attitude does not automatically translate into competent use. HR offices (DAR/ZA) therefore have a strategic role in:

- (a) planning and delivering hands-on training;
- (b) building communities of practice;
- (c) providing timely information and guidance; and
- (d) ensuring infrastructure readiness. This aligns with findings that perceptions and training influence usage intention and that HR management can shape AI adoption through culture and professional development [3]

Conclusion

This study shows that Master's students/teachers largely view AI as a positive driver of change in Human Resource Management (HRM) in education, especially for professional development, feedback, and continuous competency improvement. At the same time, the findings highlight a clear gap between willingness and readiness: respondents report a strong need for more practical, hands-on training to use AI effectively in teaching/learning and HRM processes.

Results also suggest that HR structures (DAR/ZA) should move beyond a mainly administrative, "as-needed" relationship with teachers and take a more proactive role in needs assessment, structured communication, and continuous support for qualification and digital/AI competencies. Finally, the strong emphasis on well-being and the belief that AI should reinforce not replace teachers' abilities, alongside concerns about professional identity, underline the need for ethical governance, transparency, and human oversight.

Overall, HRM in education should evolve towards a human-technology model where AI improves efficiency and decision support, while HR professionals ensure fairness, trust, and the protection of the human dimension of education.

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THE IMPACT OF DIGITAL TECHNOLOGY AND ARTIFICIAL INTELLIGENCE ON ECONOMIC DEVELOPMENT IN ALBANIA AND THE WESTERN BALKAN

Marjeta ALIAJ (KËNAÇI); Assoc. Prof. Drita LUZO (KLLAPI)

*"Eqrem Çabej" University of Gjirokaster, Economic Faculty /Public Administration Department, Albania
Corresponding author: Marjeta Aliaj (Kënaçi):marjetakenaci@gmail.com*

Abstract

In recent decades, digital technology and artificial intelligence (AI) have become major drivers of structural economic change around the world. In the Western Balkans, including Albania, the acceleration of digital transformation offers significant opportunities for economic growth and improved competitiveness, but faces significant challenges. In Albania, the data show a paradox: while technological adoption is accelerating in some enterprises, the infrastructure, skills and institutional frameworks that support the transformation are still in their infancy. This study aims to analyze the impact of digital technologies and AI on economic productivity, the labor market and sectorial growth in Albania and the Western Balkan countries. This research uses a hybrid methodology: statistical analysis of identified trends (ICT, e-commerce, and A.I. integration), sectorial comparisons for Albania and the region; and interviews with representatives of enterprises and public institutions, to understand the real barriers to technological adoption. The focus is on the key question: How does the adoption of digital technology and artificial intelligence affect productivity, employment and structural economic growth in Albania and the Western Balkans? This article proposes several strategic recommendations: 1. Increased national and private investments in digital education and training. 2. Fiscal incentives and subsidies for enterprises adopting AI and digital platforms. 3. Strengthening digital governance, legal frameworks and technological infrastructure to accelerate innovation and increase regional competitiveness. In conclusion, this research argues that without a common regional strategy and concrete implementation of advanced technologies, the digital transformation for economic development in Albania will remain fully unimplemented. By placing Albania in a broader regional context, this study contributes to the literature on the digital economy in transition countries and offers concrete lessons for policymakers, academics and practitioners.

Keywords: Digital Technology and AI, employment, infrastructure, fiscal incentives, investments.

Introduction

In recent decades, digital technology and artificial intelligence (AI) have become key drivers of structural economic change worldwide. In the Western Balkans, including Albania, the acceleration of transformation offers unique competitive opportunities for economic growth and improvement, but faces its own challenges.

Analyzing the impact of digital technology and AI on economic productivity, the labor market and the Albanian sector in Albania and the Western Balkans

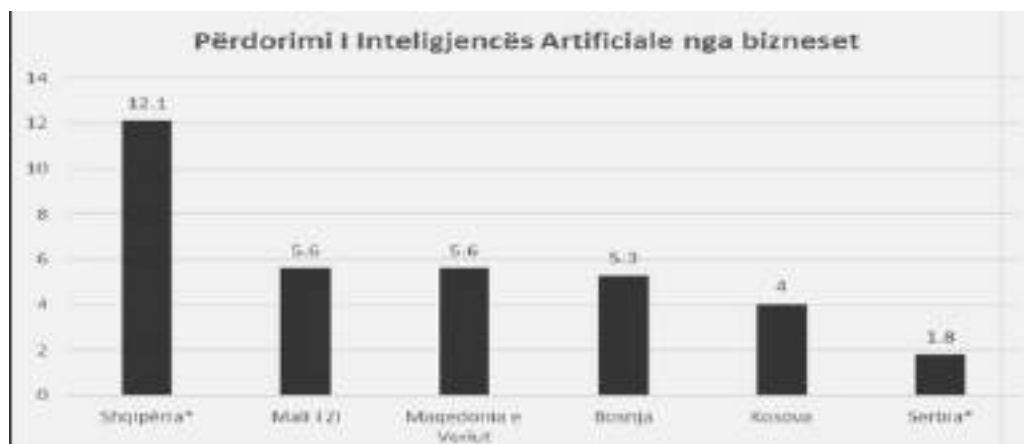
In Albania, the data reveal a paradox: while technology adoption is accelerating in some enterprises, the infrastructure, skills and institutional frameworks that support the transformation are still in their infancy.

This study aims to analyze the impact of digital technology and AI on labor productivity and the economy in the Western Balkans sector. Based on the same national code expressed by the Institute of Statistics (INSTAT), Eurostat, World Bank and OECD — this research uses a hybrid methodology: analysis of product trend statistics (ICT, e-commerce, AI integration), sectoral comparison for Albania and the region; and interviews with business and public representatives, to find real barriers to technology adoption. [1,2,3,4]

How Widespread Are Digital Technologies & AI in Albania and the Balkans?

According to the latest report of the regional index for the digital economy and society [5], there are visible advances in digital infrastructure (internet, broadband), use of technologies for businesses (website, e-invoicing, basic digitization), as well as some adoption of more "advanced" technologies. Likewise, the use of data analytics ("data analytics") reaches 33% of companies in Albania, in line with the European Union average.

Albanian businesses use Artificial Intelligence more than the Region and the EU Although Albania has a technological gap compared to the Region and EU countries, our businesses are using Artificial Intelligence (AI) more than those in the Western Balkans region, even more than the EU. According to the latest report "Western Balkan Digital Economy and Society Index 2024" by the Regional Cooperation Council, Albanian businesses lead the Western Balkans in the use of Artificial Intelligence (AI) and advanced technologies. The data shows that in 2023, 12% of Albanian enterprises will use AI, a level more than double the regional average of only 5% and above the European Union average of 7%.



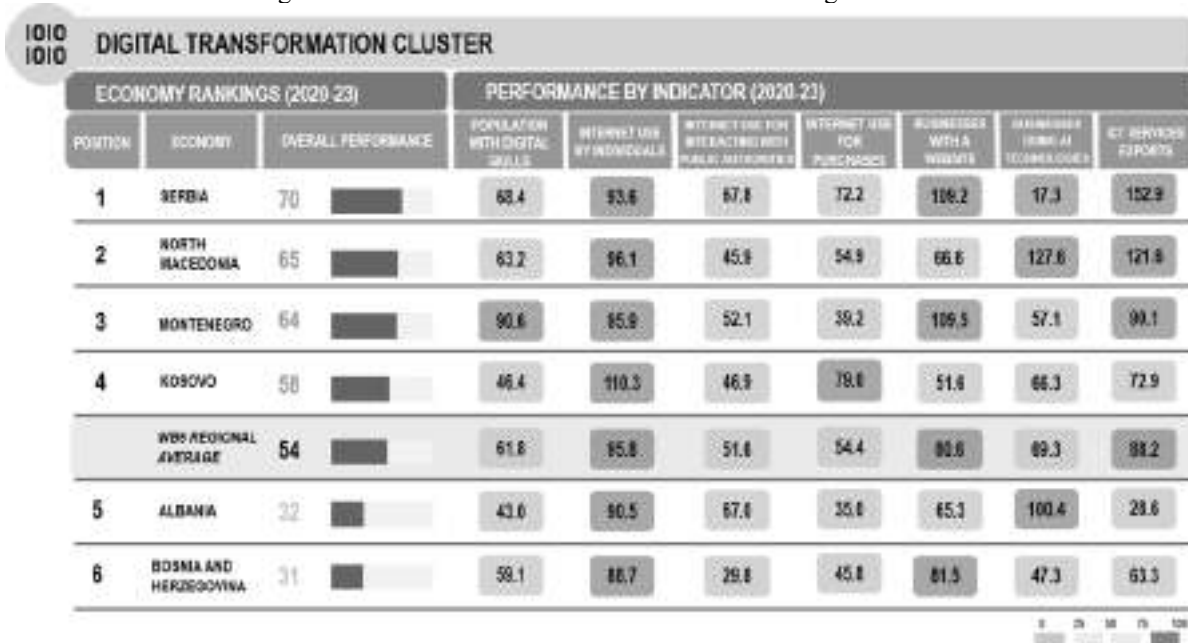
Graph 1. The use of AI from the businesses

Online engagement through social media is gradually improving. In 2023, 26% of enterprises in the Region used two or more types of social media platforms, slightly below the EU average of 31%.

The use of advanced digital technologies also shows progress in 2023. The use of cloud computing increased to 26%, however it lags the EU average of 38%. The adoption of data analytics increased significantly to 31%, almost narrowing the gap with the EU, from only 6% in 2020. Source: RCC, Albania and Serbia data 2023, others 2025 Around 5% of enterprises in

the Region reported using artificial intelligence in 2023, compared to 7% in the EU comparable to the EU, 32%. less than the EU average.

Table 1. Convergence of the Western Balkan economies with the EU: Digital transformation cluster



Digital technologies and AI are increasingly penetrating Albanian and regional businesses, but the distribution is uneven; more modern enterprises (especially ICT/services, exports, startups) advance faster, while many traditional industries and the majority of the workforce remain digitally under-skilled.

Contribution to Economic Productivity & Sectoral Growth

In an industry that never stands still, predicting the future often means focusing on the present. While these developments may seem important now, their true impact may be relatively small compared to the radical transformations expected over the coming years. What seems monumental today may simply be a small chapter in a much larger technological evolution.

The spread of digital technologies and AI offers several key channels to increase productivity and drive economic growth, especially in Albania and the Balkans:

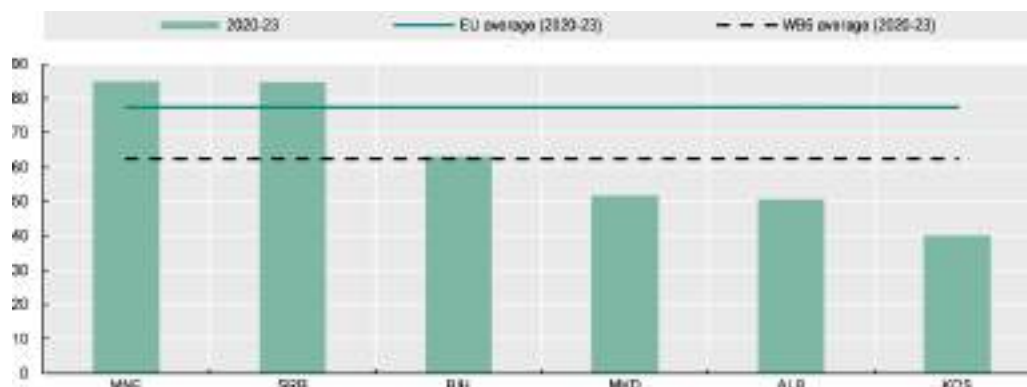
Regional studies highlight that sectors with the highest adoption of digital technologies, especially ICT, are among the main growth drivers. In the Balkans, the ICT sector constitutes an essential part of economies that export services, making these countries more globally competitive.

Despite the relative newness of the AI ecosystem, considerable progress has been made compared to 5 years ago. We now have a strong foundation in sectors such as Healthcare, Marketing, Sales and Finance, thanks to founders and investors who spent heavily to build the foundations of the ecosystem.

Global empirical studies comparing countries with different levels of digitalization (IT/digitalization) find a positive correlation between the spread of digital technologies and truly measurable economic growth.

The low rates of internet use for purchases can also be attributed in part to the relatively low proportion of businesses with websites in some Western Balkan economies. While 62.5% of businesses in the region have websites about 80% of the EU average this figure is largely driven by Montenegro and Serbia, where adoption rates exceed EU levels. In contrast, other economies lag behind, with Kosovo having the lowest rate at just 40.0%, slightly over half the EU average

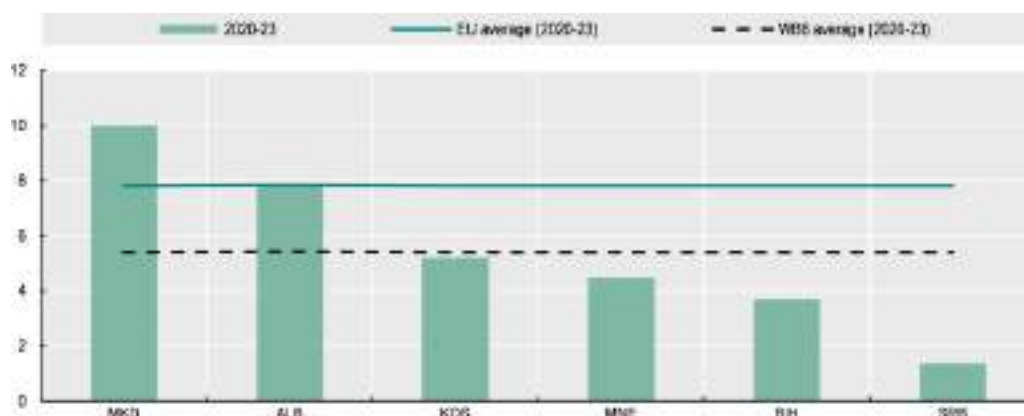
Percentage of Enterprises with 10+ Employees



Graph 2. Businesses with a website in the Western Balkans (2020-2023)

For countries like Albania that are aspiring towards closer integration with the EU, digitizing key sectors (e.g. energy, tourism, ICT) can accelerate economic modernization and diversify sources of growth. A recent report on Albania highlights these three sectors as “priorities” for digital transformation.

Improving public services with technology (e-government, e-services) can make administration more efficient, increase transparency, and save time and costs, which, in turn, increases national productivity. In Albania, a World Bank-supported project aims to increase the accessibility and efficiency of government services for citizens and businesses.



Graph 3. Proportion of enterprises using AI technologies in the Western Balkans (2020-23). Percentage of all enterprise

For Balkan countries, and Albania in particular, the adoption of digital technologies and AI can increase productivity, diversify into high-value sectors, and strengthen competitiveness, but these benefits depend heavily on workforce skills and infrastructure investments.

Impact on the Labor Market, Employment and Skills Opportunities & Challenges

The changes brought about by digitalization and AI are also strongly affecting the labor market. AI startups in this region have secured over 1.4 billion euros in funding during 2023 and 2024. Key sectors where AI is impacting CEE.

Healthcare and life sciences: AI technologies are being used for diagnostics, biomedical analysis and the development of personalized therapies.

Marketing and sales: AI is helping to personalize the customer experience and automate marketing campaigns.

Finance and banking: The technology is being used to detect financial fraud, analyze consumer behavior and improve banking operations.

Manufacturing and industry: AI is automating production lines, reducing costs and increasing efficiency.

Cybersecurity: AI algorithms help identify and prevent cyberattacks.

Challenges and Risks of Artificial Intelligence

A major problem is the large digital skills gap: only a relatively small part of the population has “basic digital skills”, while intermediate/advanced skills are even rarer. In-house training is insufficient and many companies do not offer adequate retraining to their employees. As a result, a division in the labor market may be created: those who have digital skills (or who invest in them themselves) will benefit; others may remain marginalized even though digitalization aims to increase productivity.

In some cases, not only may manual or routine jobs be reduced, but there may be a risk of displacement of workers, especially in traditional industries that do not invest in retraining.

It is important to emphasize, as regional reports also point out, that to really benefit from digitalization, investments must be made in education and training, in improving infrastructure, and in social inclusion policies.

Factors that Determine the Success (or Failure) of Digitalization and AI for Albania & the Balkans

As we continue to navigate the evolving AI landscape, with monthly updates on developments such as the latest OpenAI round, political engagement is intensifying due to concerns about the potential risks and impacts.

Several key factors emerge from the literature and relevant reports:

Workforce skills Without adequately trained people, the adoption of modern technologies will be limited. In the Balkans, digital skills figures remain far behind the EU.

Training and development of human capital education in STEM, ICT, digital skills, software training, digital management, data analytics, etc. should be considered.

Digital infrastructure and investments fast broadband, ICT infrastructure, access to modern devices, etc. Without fulfilling these points, any areas (especially rural ones) are left behind. It should be born in mind that if investment in this infrastructure and its security is not realized, many businesses will have problems in their efficient performance, for example, some businesses that have suffered a cyber-attack have had the following consequences:

1. Damage to the brand;
2. Loss of clientele;
3. They have lost the opportunity to attract new clientele;

4. They have lost the opportunity to expand their activities.

State/regulatory policy & support for the private sector when there are initiatives for digitalization, training, investments, and funds for SMEs that modernize increases the probability of success.

Employee readiness: desire to adapt, flexibility, willingness to learn. Without willingness to adapt skills, external changes will not become productive.

Inclusive approaches to not leave certain groups behind (age, rural areas, women, vulnerable categories). Digital transformation must be for “everyone,” otherwise it increases inequality.

Advantages and Disadvantages of Artificial Intelligence in Albania and Measures Taken by Relevant Institutions and the European Union

The biggest discussions regarding the acceptance or not of artificial intelligence are related to the costs it has. Like many automations, AI supports cost minimization as it reduces the need for a lot of personnel and time. Many researchers state that companies can significantly reduce time by adopting appropriate AI applications in the decision-making process, which leads to a reduction in operational costs [6].

On the other hand, the cost reduction in human resources is associated with high costs to build and maintain an artificial intelligence algorithm or platform. One of the main disadvantages of artificial intelligence is the cost of maintenance and repair. The software must be constantly updated to meet changing requirements. In the event of a breakdown, the cost of repair can be very high. [7]

Another discussion related to the application of artificial intelligence concerns legal and ethical issues. This is related to the lack of transparency in matters related to data security. While the advantages and disadvantages of using AI in different fields or industries are found in the table below.

Table 2. Pro and cons Artificial intelligence

Advantages	Disadvantages
Reduces time and costs	Increases unemployment rate
Eliminates human error and risk	It is fallible
Improves management systems	Reduces creativity and increases laziness
Reduces needs	Infringes copyrights (Chats and AI for production)
Enables unbiased decision-making	It lacks emotions and creativity
Performs repetitive tasks	It brings psychosocial degradation
Retrieves and analyzes data	There is no improvement with its own experience
Serves as a digital assistant	Reduced jobs for people
Applies to everyday life	Many ethical problems
Tracks new inventions	Problems with privacy and data security
Increased security	Lack of transparency and explainability
Identifies best human workflows	Creating addiction and has low reliability
Identifies patterns used	Increases the possibility of fraud
Available 24/7	Its implementation is costly

Use of AI in Albania

In our country, the use of artificial intelligence is not at the desired levels. Although we have progressed from year to year, the use of AI compared to developed countries is very low. The situation is similar when compared to the region. The Artificial Intelligence Readiness Index for 2021, published by Oxford Insights, ranks Albania in 83rd place out of 160 countries in total.

The Albanian Association of Bankers dedicated the 33rd issue of the “Bankieri” magazine in 2019 to artificial intelligence, which makes you understand that this sector is interested in its use. The embrace of AI in the banking system starts with queue robots, interactive ATMs and even smart applications or Chat bots on websites.

A sector that has been greatly affected by the use of AI is that of marketing and visual communication. There are many AI platforms that serve various functions in the field of communication and marketing, from multimedia content creation platforms to text generation platforms, which have taken their place in the use of social network management.

Another issue that has raised the concern of experts is the use of AI in the education sector and the increased possibility of fraud.

Recommendations: How to Accelerate and Optimize the Positive Impact of Technologies in Albania and the Balkans

Considering the above points, we propose some recommendations that can help us how to optimize.

Serious investment in digital education and training in schools, universities, for young and old; inclusiveness for less trained groups.

To ensure further success, countries in the region need to invest more in educating AI talent, strengthen links between universities and industry, and create a favorable environment for international investors. With the right measures, CEE can become a dominant force in AI innovation in the coming decades.

Boosting digitalization in key sectors (tourism, energy, public services, ICT) through subsidies, initiatives, and policies that support SMEs and startups.

Strengthening digital infrastructure across the territory broadband, fast internet access, equipment to not leave rural areas behind.

Promotion of cooperation between public institutions, universities, and the private sector to ensure that training and research match market needs.

This article proposes several strategic recommendations:

1. Increase national and private investments in digital education and training
2. Development of modern curricula and training centers
 - Introduction of practical modules: AI, data literacy, coding, cloud computing, cybersecurity.
3. Increase of private investments
 - Investments in staff training with Train-to-Hire and Training Vouchers schemes.
 - Financing ed-tech start-ups and digital learning platforms.
4. Technology as a tool for increasing productivity
 - Increasing efficiency in business and administration.
 - A more competitive workforce with digital skills.
 - Reducing the informal economy through digitalization.

5. National and regional strategies

- Regional certification of digital skills for the Western Balkan countries.
- Harmonization with EU standards and platforms for digital transformation.

6. Beneficial investments for the population

- Free training for citizens.
- Professional training for teachers and administration.
- Subsidies for access to computers and the internet in rural areas.

Conclusions

Digital education and training are the most important investment for increasing productivity and economic development in Albania. With sustainable policies, public-private partnerships, and a focus on digital capabilities, the country can increase its competitiveness and economic well-being.

This research argues that without a common regional strategy and concrete implementation of advanced technologies, digital transformation for economic development in Albania will remain fully unimplemented. By placing Albania in a broader regional context, this study contributes to the literature on the digital economy in transition countries and offers concrete lessons for policymakers, academics, and practitioners.

Albania has considerable potential to benefit from digital transformation and AI. This transformation requires coordinated cooperation between government, the private sector, universities, and international organizations.

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THE ROLE OF SUSTAINABLE TOURISM IN REGIONAL ECONOMIC DEVELOPMENT: EVIDENCE FROM SOUTHERN ALBANIA

Lecturer M.Sc. Mirtila LLUKANI¹; Assoc.Prof. Drita LUZO (KLLAPI)²; M.Sc. Briselda HUSO³

¹*“Eqrem Çabej” University, Economic Faculty, Department of Economic Policies and Tourism, Albania*

²*“Eqrem Çabej” University, Economic Faculty, Finance-Accounting Department, Albania*

³*M.Sc. Briselda Huso, Economist, Private Firm, Gjirokastër, Albania*

Corresponding author - M.Sc. Mirtila Llukani: tilallukani@gmail.com

Abstract

This paper examines the role of sustainable tourism in promoting regional economic development, focusing on Southern Albania as a case study. The purpose of the study is to analyze how sustainable tourism practices contribute to local economic diversification, employment growth, and the preservation of natural and cultural resources. The research employs a mixed-method approach, combining secondary data analysis from national tourism statistics with qualitative insights collected through interviews with local stakeholders, including tourism operators and municipal representatives. The study emphasizes the interconnection between environmental sustainability, community participation, and economic competitiveness. The expected findings suggest that regions implementing sustainable tourism policies experience more resilient growth patterns and improved socio-economic outcomes. Moreover, the paper highlights key challenges related to infrastructure, policy coherence, and human capital that must be addressed to enhance sustainability in tourism development. The results aim to provide practical recommendations for policymakers and regional planners to strengthen the contribution of tourism to balanced and inclusive economic development in Albania.

Keywords: Sustainable tourism, regional development, Southern Albania, economic growth, sustainability policies, community participation

1. Introduction

Tourism has become one of the most dynamic economic sectors globally, providing significant contributions to employment, income generation, and regional competitiveness. In recent years, the concept of sustainable tourism has gained substantial importance as destinations increasingly seek development models that balance economic growth with environmental protection and social well-being. This shift is particularly relevant for countries like Albania, where tourism potential is high but infrastructure, governance, and human capital still face notable constraints.

Southern Albania—characterized by its pristine beaches, rich cultural heritage, and diverse natural landscapes—has emerged as one of the country’s most promising tourism regions. Cities and towns such as Saranda, Himara, Gjirokastra, Përmet, Dhërmi, Ksamil, and the wider Riviera area attract both domestic and international tourists. However, rapid and sometimes

unplanned development raises concerns regarding environmental degradation, uneven local benefits, and pressures on cultural sites and ecosystems. The need for sustainable development models has never been more critical.

This study aims to examine how sustainable tourism practices contribute to regional economic development in Southern Albania, focusing on economic diversification, employment creation, community involvement, and the conservation of natural and cultural resources. The paper adopts a mixed-method approach, integrating quantitative data from national tourism indicators with qualitative insights gathered from interviews with tourism operators, local authorities, and community representatives.

The analysis contributes to the broader academic debate on tourism-led development by highlighting the conditions under which sustainable tourism can become a driver of inclusive growth. It also provides practical recommendations for policymakers and regional planners seeking to enhance both the sustainability and competitiveness of tourism in Albania.

2. Literature Review

2.1 Sustainable Tourism as a Development Strategy

Sustainable tourism is defined by the United Nations World Tourism Organization (UNWTO) as tourism that “*meets the needs of present tourists and host regions while protecting and enhancing opportunities for the future.*” [1].

The concept integrates three dimensions:

1. Environmental sustainability
2. Economic sustainability
3. Socio-cultural sustainability

Studies have widely analyzed the role of sustainable tourism in promoting regional development. Research by Sharpley [2], Bramwell & Lane [3] shows that sustainable tourism increases long-term benefits by preserving natural resources, enhancing local participation, and fostering diversified economic activities.

2.2 Tourism-Led Regional Development

Tourism is often considered a catalyst for regional development, especially in peripheral or rural regions. Its impact includes:

- Employment creation
- Stimulating local entrepreneurship
- Improving infrastructure
- Increasing fiscal revenues
- Enhancing cultural exchange and heritage preservation

However, scholars warn about risks such as overdependence on tourism, environmental damage, and seasonal labor patterns. Sustainable management is essential to mitigate these effects.

2.3 The Albanian Context

Albania has undergone significant tourism expansion in the last decade. The Riviera has witnessed increases in visitor numbers, new accommodation capacities, and improved mobility

infrastructure. While this has generated economic momentum, issues such as urbanization, waste management, informal construction, and lack of professionalized labor remain challenges.

Existing research [4; 5] highlights the potential of sustainable tourism for Albania, but also the need for strategic planning and community involvement. There is still limited empirical research that focuses specifically on Southern Albania as a case for sustainable tourism development.

This study aims to fill that gap.

3. Methodology

3.1 Research Approach

The study employs a mixed-method approach, combining:

Quantitative analysis of national tourism statistics [6], [7], regional development reports.

Qualitative interviews with 25 stakeholders, including:

- Local business owners (hotels, restaurants, tour operators)
- Municipality officials from Saranda, Himara, Gjirokastër, and Përmet
- Representatives of tourism associations and community groups/

3.2 Data Collection

Quantitative data include:

- Tourism arrivals and overnights (2015–2024)
- Employment figures in accommodation and food services
- Infrastructure indicators
- Investment flows in tourism-related projects
- Qualitative data include semi-structured interviews focused on:
 - Evaluation of sustainable tourism policies
 - Challenges in implementing sustainability standards
 - Perceived benefits for local communities
 - Environmental preservation efforts

3.3 Data Analysis

Quantitative data were analyzed using descriptive statistics to identify trends.

Qualitative responses were coded thematically, focusing on categories such as:

- Community involvement
- Environmental management
- Economic opportunities
- Institutional challenges

4. Findings

4.1 Economic Diversification and Local Entrepreneurship

Tourism in Southern Albania has stimulated new business ventures in:

- Accommodation services (boutique hotels, guesthouses)
- Gastronomy and local cuisine

- Adventure tourism (rafting in Vjosa, hiking in Nivica, canyoning in Bënçë)
- Cultural tourism linked to Gjirokastra's UNESCO heritage
- Stakeholders emphasized that sustainable tourism promotes the use of local products, such as organic food, handmade crafts, and traditional services, thereby diversifying the regional economy beyond seasonal beach tourism.

4.2 Employment Growth and Human Capital Development

Tourism has become one of the largest employers in the region. The study finds that:

- Seasonal employment remains dominant, but sustainable tourism initiatives have created more year-round opportunities.
- Training programs in hospitality and ecotourism often supported by donor agencies have improved service quality.
- Youth participation is notably high, especially in Himara and Saranda.
- However, stakeholders stressed the need for:
 - More vocational training
 - Better language proficiency
 - Certification in sustainable hospitality practices

4.3 Environmental and Cultural Resource Preservation

Interviewees consistently highlighted that sustainable tourism depends on:

- Clean coastlines
- Protected natural parks (Butrint, Llogara, Vjosa River)
- Preservation of cultural heritage sites
- Positive examples include:
 - The Butrint National Park management project
 - Community-led waste reduction initiatives in Përmet
 - Restorations in old Gjirokastra
- Yet, challenges persist such as:
 - Uncontrolled construction
 - Waste management deficiencies
 - Pressure on fragile ecosystems during peak season

4.4 Community Participation

A key finding is that sustainable tourism is more effective where communities actively participate in planning and benefit-sharing. Examples include:

- Himara's community involvement in regulating informal construction
- Përmet's "Slow Food" initiatives promoting local products
- Gjirokastra's artisan markets supporting women entrepreneurs
- Where community involvement is weak, sustainability outcomes tend to be lower and conflicts between stakeholders more common.

4.5 Infrastructure and Policy Challenges

Despite progress, stakeholders identified the following issues:

- Fragmented tourism governance
- Inconsistent implementation of sustainability standards
- Limited public infrastructure (parking, wastewater systems, transport networks)
- Weak coordination between municipalities and central government
- These constraints limit the potential of sustainable tourism to fully contribute to regional development.

5. Results

Findings confirm that *sustainable tourism in Southern Albania*:

- Generates broad socio-economic benefits
- Strengthens regional competitiveness
- Encourages environmental stewardship
- Enhances community cohesion and cultural identity

However, the region risks falling into a cycle of unsustainable mass tourism, similar to patterns observed in parts of Greece, Croatia, and Spain, if planning and regulations are not strengthened. The study suggests that sustainable tourism should not be viewed as an alternative form of tourism but as an integrated development model.

Key strategic priorities include:

- Institutional coordination and policy coherence
- Environmental protection as an economic asset
- Local community empowerment
- Investment in human capital
- Diversified tourism products (eco, cultural, adventure, gastronomy)

6. Conclusion

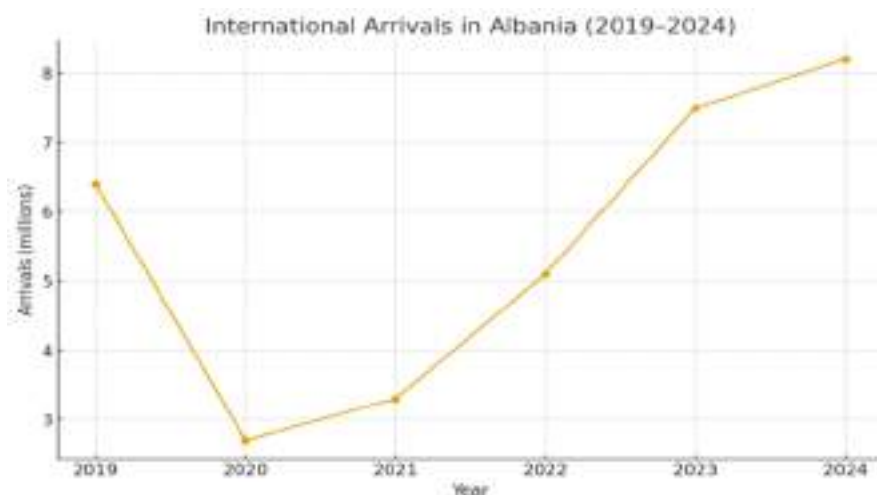
Sustainable tourism has significant potential to drive regional economic development in Southern Albania by:

- Diversifying local economies
- Creating employment
- Preserving natural and cultural assets
- Enhancing community participation

However, to maximize these benefits, Albania must address critical challenges related to infrastructure, governance, and human capital. Policymakers should adopt long-term planning strategies, enforce construction regulations, improve waste management systems, and promote sustainable certifications for tourism businesses. If managed effectively, sustainable tourism can serve not only as an engine of growth but also as a pillar of social inclusion and environmental protection, ensuring that Southern Albania remains a competitive and resilient destination for future generations.

Table 1. Tourism arrivals trend

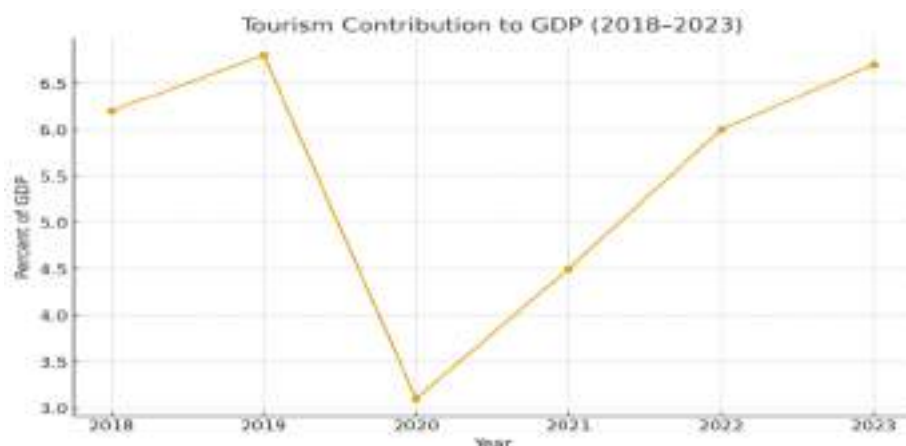
Year	Arrivals (000s)	Revenue (M€)
2019	120	310
2020	90	200
2021	130	280
2022	150	350



Graph 1. International Arrivals (2019–2024)

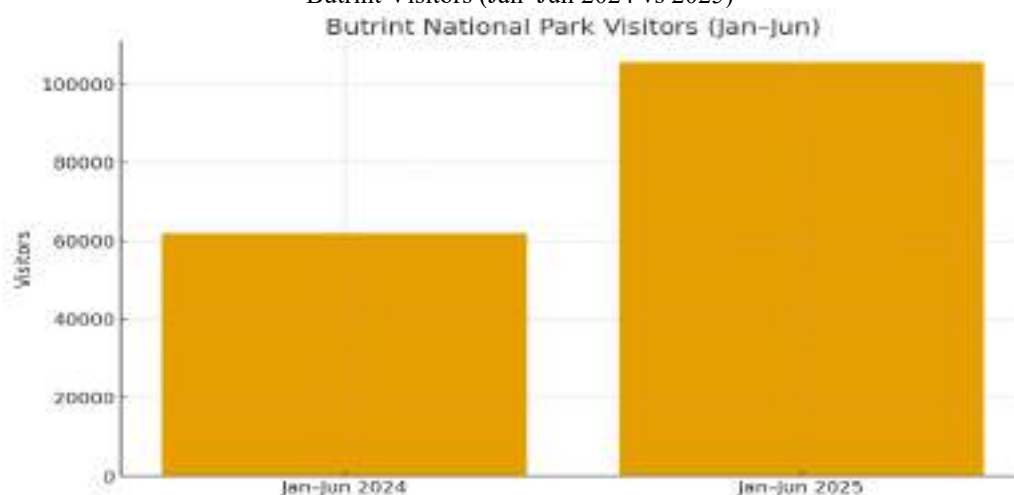
Table 2. Tourism arrivals and revenues trend

Region	Tourists 2023	Accommodation Units	Employment in Tourism
Vlora	1400000	1450	12800
Gjirokastra	520000	410	5400
Saranda	980000	860	7200



Graph 2. Tourism contribution to GDP (2018-2023)

Table 3. Butrint National Park Visitors Jan–Jun 2024 vs 2025
Butrint Visitors (Jan–Jun 2024 vs 2025)



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ARTIFICIAL INTELLIGENCE AS A DRIVER OF MANAGERIAL INNOVATION: DIGITAL TOOLS FOR RISK EVALUATION AND BANKRUPTCY PREVENTION

Assoc. Prof. Ioana Monica HORJA Ph.D.; Assoc. Prof. Eleonora Laura AVRAM Ph.D.

“Dimitrie Cantemir” University of Targu Mureș, Romania, Faculty of Economic Sciences, Romania
Corresponding author: Ioana Monica Horja: moni_horja@yahoo.com

Abstract

Artificial intelligence (AI) is increasingly embedded in managerial work through analytics platforms, automation, and decision-support systems. Building on the provided article, this paper develops a scientific discussion of AI as a driver of managerial innovation, with a focused application to risk evaluation and bankruptcy prevention. We synthesize relevant research on managerial innovation, dynamic capabilities, and data-driven decision making, and we propose an AI-enabled risk management framework that combines early-warning indicators, predictive modelling, and actionable managerial interventions. A conceptual case is used to illustrate how firms can integrate machine-learning predictions with governance routines to shift from reactive crisis response to proactive resilience building. We further discuss implications for managerial education, highlighting the competencies required to interpret model outputs, manage algorithmic risk, and align digital tools with ethical and regulatory constraints. The paper concludes with research directions and practical recommendations for deploying AI in financially sensitive decision contexts.

Keywords: artificial intelligence, managerial innovation, decision support, predictive analytics, risk evaluation, bankruptcy prediction, early-warning systems, dynamic capabilities

Introduction

The rapid digital transformation of the global economy has redefined the way organizations manage risk, make decisions, and maintain competitiveness. Among emerging technologies, *Artificial Intelligence (AI)* has become a cornerstone of managerial innovation, offering new opportunities to enhance analytical capabilities and operational efficiency.

Organizations operate in environments characterized by digital disruption, volatility and accelerated competitive cycles. In this context, managerial innovation - the adoption of new managerial practices, structures and processes becomes a critical lever for sustaining performance. AI contributes to this innovation by expanding the informational basis of decisions and by enabling automation of routine coordination tasks. For financially exposed companies, AI can be especially valuable by identifying early signals of distress and supporting timely corrective action.

The paper tries to examine the theoretical foundations linking AI and managerial innovation, a possible model of architecture of AI-based tools for risk evaluation and bankruptcy

prevention, a conceptual methodology and a hypothetical case and the implications for governance and managerial education.

A Few Aspects of Managerial Innovation

Managerial innovation has been studied as a complement to technological innovation, emphasizing changes in planning, control, and coordination that improve organizational effectiveness. Managerial innovation refers to the implementation of new management practices, processes, or structures that improve organizational performance [1].

The resource-based view and dynamic capabilities perspective highlight that competitive advantage depends not only on assets but also on the ability to sense changes, seize opportunities, and reconfigure resources. AI strengthens these capabilities by converting large volumes of operational and market data into signals that guide managerial attention.

In recent years, innovation has increasingly been driven by digital technologies, particularly AI, which enable managers to process large volumes of data and derive actionable insights.

Scholars such as Davenport and Ronanki [2] highlight that AI supports decision-making by automating analytical processes and augmenting human judgment rather than replacing it.

Digitalization, as defined by Vial [3], represents the integration of digital technologies into all business operations, fundamentally transforming how organizations create value. Within this context, AI acts as both a *tool* and a *driver* of digital transformation, influencing strategic management, financial control, and organizational resilience [4].

In risk management literature, traditional models of financial distress prediction—such as Altman’s Z-score [5] relied heavily on static financial ratios. The predictive models have evolved to incorporate non-financial data, dynamic indicators, and real-time analytics, advancements which enable more precise risk evaluation and proactive managerial interventions.

From an information-processing standpoint, organizations face bounded rationality and uncertainty. Digital tools can reduce information asymmetry and improve forecasting, but they also introduce new dependencies like data quality, model validity or cybersecurity that must be managed. Consequently, AI-enabled managerial innovation is best understood as a socio-technical change that combines algorithms, data, human judgment, and institutional controls.

AI has transformed the managerial landscape by enabling data-driven innovation in decision-making processes. AI-driven innovation is characterized by the synergistic interaction between human creativity and machine intelligence. Managers can leverage AI systems for forecasting, scenario simulation, and optimization of strategic choices.

From a managerial perspective, AI enhances three core areas of innovation:

Decision Support and Automation – Machine learning algorithms analyze vast datasets to identify trends and correlations that might escape human analysis.

Predictive and Prescriptive Analytics – AI not only predicts future risks but also recommends optimal strategies to mitigate them.

Knowledge Management – Natural language processing (NLP) tools and intelligent dashboards enable managers to synthesize unstructured information into meaningful insights.

Moreover, AI promotes a culture of *adaptive learning* within organizations. By automating repetitive analytical tasks, it allows managers to focus on creativity, innovation, and strategic foresight — skills that are increasingly vital in education and leadership development programs [6].

In any case, should not be understood that AI remove the need for managerial judgment. Models can produce probabilistic outputs, but these outputs must be interpreted in context, and

they can reflect bias if training data are unrepresentative. Therefore, effective adoption depends on complementary practices such as model governance, explainability, and cross-functional collaboration between finance, operations, and data science teams.

Digital Tools for Risk Evaluation and Bankruptcy Prevention

The digitalization of risk management has led to the emergence of AI-based tools that revolutionize how organizations monitor financial health. Predictive analytics platforms integrate financial data, market signals, and behavioural indicators to forecast potential bankruptcy scenarios. According to Bellovary, Giacomino, and Akers [7], early warning models are critical for detecting financial distress; however, their accuracy increases substantially when AI is applied.

Financial distress typically emerges through patterns such as deteriorating liquidity, rising leverage, declining profitability, and worsening working-capital cycles. Traditional risk evaluation relies on ratio analysis and periodic reviews, which may be too slow for fast-changing conditions. AI-based early-warning systems can integrate internal accounting data with external signals like macro indicators, sector demand or payment behaviour in order to estimate default probability and to detect anomalies.

AI-based bankruptcy prediction models can continuously learn from new data, allowing for dynamic adaptation to changing market conditions. Additionally, AI supports *real-time monitoring systems* that track liquidity, cash flow, and credit risk indicators, providing managers with actionable alerts before crises escalate.

In practice, companies are integrating AI into Enterprise Risk Management (ERM) systems to ensure a holistic view of organizational vulnerabilities. The combination of AI and digital dashboards fosters transparency and accountability, improving governance and strategic resilience. As a result, bankruptcy prevention becomes not only a financial necessity but also a dimension of sustainable and innovative management.

Bankruptcy prediction has a long research tradition starting with statistical discriminant analysis and models. These models often achieve higher predictive accuracy, but they may be less transparent. In managerial settings, the design challenge is to balance accuracy with interpretability so that model outputs can support accountable action.

The AI-enabled risk management workflow can be structured in four stages:

- a) data integration and quality control;
- b) model-based prediction and stress testing;
- c) translation of signals into managerial decisions via dashboards and alert systems;
- d) organizational response routines, including cost optimization, renegotiation of financing, portfolio reprioritization, and operational reconfiguration.

Study case

The study follows a qualitative and conceptual design, combining a structured literature synthesis with scenario-based modelling. First, prior research on AI adoption, managerial innovation, and financial distress prediction is reviewed to derive key constructs and mechanisms. Second, an illustrative scenario is developed to demonstrate how an AI-enabled early-warning system can inform managerial interventions. Third, the capabilities and limitations of digital tools are assessed in relation to governance requirements and managerial learning outcomes.

Although the case is conceptual, it is designed to reflect typical data inputs and decision processes in medium-to-large enterprises. The goal is not statistical generalization but analytical generalization: to clarify how AI tools can be embedded into managerial routines for proactive risk management.

The research focuses on *EuroRetail Group*, a fictitious European retail company facing challenges related to market volatility, changing consumer behaviour, and financial sustainability. Data collection relies on secondary sources, including academic literature on AI in management, digital tools for risk evaluation, and bankruptcy prevention.

The methodological approach includes:

Literature synthesis – analyzing prior studies on AI-driven managerial tools and predictive financial analytics.

Scenario modelling – constructing a hypothetical financial scenario for EuroRetail Group to demonstrate AI-based risk evaluation.

Evaluation of digital tools – assessing the potential impact of AI-driven dashboards, predictive algorithms, and automated decision-support systems on both risk prevention and managerial learning.

So, the retail group experience margin pressure due to higher input costs and weaker demand. The company collects monthly accounting data (cash, receivables, inventory, payables, debt service) and operational data (store traffic, conversion rates, stock-outs). An early-warning model is trained on historical company and sector data to predict the likelihood of distress within a 6–12-month horizon.

When the model flags elevated risk, the system surfaces the most influential drivers (e.g., declining cash ratio, slower receivables turnover, increasing short-term leverage). Managers then evaluate intervention options such as tightening credit policies, optimizing inventory, renegotiating supplier terms, and pausing capital expenditures. The value of AI in this setting is twofold: it accelerates detection and it supports disciplined prioritization by linking actions to quantified risk drivers.

Nonetheless, implementation raises managerial and ethical issues. Data pipelines must be secured; model performance should be monitored for drift; and decision authority must remain clear. Overreliance on automated scores can lead to complacency, while underutilization can waste investment. A balanced approach uses AI as an augmenting tool within well-defined governance processes.

Implications for Managerial Education and Practice

AI-enabled managerial innovation requires skills that combine domain expertise with data literacy. Managers need to understand how predictions are produced, what assumptions underlie models, and how uncertainty should shape decisions. Key competencies include interpreting dashboards, asking critical questions about data quality, collaborating with technical specialists, and applying ethical principles when algorithmic recommendations affect employees, customers, or creditors.

For organizations, practical steps include the following:

- establishing a cross-functional model governance board;
- defining risk thresholds and escalation paths;
- investing in explainable analytics;
- embedding learning loops that compare predicted versus realized outcomes.

In regulated environments, compliance with data protection and AI governance frameworks must be ensured.

Conclusions

AI can act as a catalyst for managerial innovation by enabling proactive risk evaluation and supporting earlier, better-targeted interventions against financial distress. Yet value creation depends on socio-technical integration: high-quality data, fit-for-purpose models, transparent decision processes, and managerial capabilities. Future research should investigate longitudinal impacts of AI tools on organizational resilience, explore hybrid human-AI decision designs, and assess how regulatory requirements influence adoption in financially sensitive contexts.

This study is conceptual and therefore does not estimate causal effects or predictive accuracy on a real-world dataset. The illustrative case simplifies complex financial dynamics and assumes the availability of timely, high-quality data. Future research should test the proposed framework with longitudinal firm-level data, compare alternative model families (e.g., gradient boosting, survival models, and neural architectures), and evaluate the organizational conditions that shape adoption (data governance maturity, managerial trust, and regulatory exposure). Additional work is also needed to quantify how AI-assisted early warning changes the timing and quality of managerial interventions, and to develop educational interventions that improve model literacy without over-reliance on automated recommendations.

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THE VARIABLE COSTS METHOD AND PRACTICAL METHODS OF CALCULATING THE BREAKEVEN POINT AND BASIC INDICATORS SPECIFIC TO CVP (Cost-Volume-Profit) ANALYSIS

Prof. univ. Ioan RUS Ph.D.

“Dimitrie Cantemir” University of Targu Mureș, Romania, Faculty of Economic Sciences, Romania
Ioan Rus: rus_nelu10@yahoo.com

Abstract

Nowadays every company should calculate the costs for its own production, using cost calculation methods of total integral type and methods of limitative, partial type. The practice of cost calculation shows that the choice of methods, procedures and techniques in cost calculation is influenced by the technology and production organization. The system of calculation for partial costs has evolved so that nowadays, according to the expenses that are part of the partial costs we can distinguish: direct costing method (variable costs) and direct costs method. Variable or direct costing method according to which production and dispatch expenses are separated and classified according to their character to the variation of production physical value and dispatch in: variable or operational expenses and structural or fixed expenses. In calculating the unit price cost only the variable expenses are considered, fixed expenses being deducted on the total from the gross financial result of the enterprise. In the case of direct costs method, production and dispatch expenses are separated and classified according to their way of identification the moment they are drawn on products, services, into direct expenses and indirect expenses. In calculating the unit product price only the direct expenses are considered, indirect expenses being deducted on the total from the gross financial result of the enterprise. We may conclude that, both methods do not intend to establish the cost for each product taken separately, but calculation and analysis of total profitability at enterprise level; the contribution or gross profit margin can be calculated for each product. Therefore, in both methods two margins can be calculated: one related to variable costs and another in connection with direct expenses. The method of variable costs in its basic form has several characteristics that individualize it and conferred upon it the status of method.

Keywords: the costs, variable expenses, breakeven point, calculation, covering contribution

Introduction

Nowadays every company should calculate the costs for its own production, using cost calculation methods of total integral type and methods of limitative, partial type.

The practice of cost calculation shows that the choice of methods, procedures and techniques in cost calculation is influenced by the technology and production organization.

Administrative accounting of integral costs is approached through a number of methods of calculation with planned costs methods, of which the following can be mentioned:

- global methods,
- methods on production phases;
- methods through orders.

Additional, more modern methods can be used such as: *Standard-Cost, (Estimated cost System) Georges Perrin, (Taux heure-Machine), (THM), Pert-Cost (Program Evaluation and Review)*.

Classical methods for the calculation of production costs that are based on planned costs are frequently used in our country for both products and work, as well as services. They presuppose two-fold calculations regarding the production cost, i.e. ante-calculation and post-calculation and by comparing the two situations (indexes) deviations from the ante-calculated costs can be established and periodic control of correspondence between effective post-calculated costs and their ante-calculated level [1]; [6].

These methods of integral (absorbant) cost calculation present a series of drawbacks, such as a large amount of work and calculation consumption that is generated through the two series of calculations, the differences being known only at the end of the period.

Methods of calculation for integral costs lead to the complete cost, delineating among direct and indirect costs. Although this complete cost has a well-established place in the literature and in practice, it is sometimes insufficient in the short-range administration. Methods of absorbance calculation lose their force due to the rapid evolution of production techniques, growth of indirect costs and of the cost of computing financial-accounting information, the long-time duration necessary for computing this information; therefore, methods of calculation of the limitative type are employed, as they limit the content of the production cost strictly to expenses that depend directly on the production and delivery amount.

The purpose of partial cost calculation methods is operative determination of profitability of productive subdivisions and of the obtained products. In this respect, the contribution of each product to covering fixed expenses of structure is determined and distribution of these expenses according to arbitrary calculations is renounced.

The first limitative (partial) method of cost calculation is attributed to the American economist Donaldson Brown who elaborated a direct costing calculation in 1923 and he was then followed by JH Harris in 1931 and G. Charter Harison in 1934: the direct costing method is known as the method of variable costs, the product cost including only variable and not fixed costs.

The system of calculation for partial costs has evolved so that nowadays, according to the expenses that are part of the partial costs we can distinguish:

- a) direct costing method (variable costs) and
- b) direct costs method.

a) variable or direct costing method according to which production and dispatch expenses are separated and classified according to their character to the variation of production physical value and dispatch in:

- variable or operational expenses;
- structural or fixed expenses;

In calculating the unit price cost only the variable expenses are considered, fixed expenses being deducted on the total from the gross financial result of the enterprise.

Within this calculation method of partial costs, the following stages are covered:

- registration of the turnover and of the revenue, respectively, in the accounts open for each product;
- registration of expense components of partial costs in the open accounts for products;
- establishing the gross contribution to covering the stage expenses and formation of the final financial result;
- discount of the stage expenses on the total gross contribution and establishment of the final economic-financial result.

b) In the case of *direct costs method*, production and dispatch expenses are separated and classified according to their way of identification the moment they are drawn on products, services, into:

- direct expenses;
- indirect expenses.

In calculating the unit product price only the direct expenses are considered, indirect expenses being deduced on the total from the gross financial result of the enterprise.

We may conclude that, both methods do not intend to establish the cost for each product taken separately, but calculation and analysis of total profitability at enterprise level; the contribution or gross profit margin can be calculated for each product.

Therefore, in both methods two margins can be calculated: one related to variable costs and another in connection with direct expenses.

The method of variable costs in its basic form has several characteristics that individualize it and conferred upon it the status of method. These are [2]; [6]:

1. uses the expenses behavior in order to divide them into variable (included in the costs) and fixed (not included)
2. specific calculation is based on indices that build judgments, support the management decisions
3. mutual services between different organizational segments and discounted at the level of variable expenses that are imputable to cost bearers;
4. it is not just a cost calculation but a results calculation for the short run, a useful tool in company management, the main objective being the short run decision making.

The following primary indices are necessary [1]; [2]; [7]:

1. Unit Cost (UC*) including variable expenses represented especially by: raw materials and materials, salaries and social security contribution for employed staff, electricity and heat for technologic processes, etc.

In order to determine the unit cost on each cost bearer, collection of variable expenses and correct identification of the physical production are necessary.

The calculation is as follows:

$$UC_i^* = \frac{i VE}{Q_i}$$

Where:

VE = variable expenses
Q = manufactured and sold production
i = cost bearer

2. Covering Contribution (Cc) or Contribution Margin

- represents the contribution of each product to obtaining the result (profit/loss) and implicitly of covering the fixed expenses. The value of the covering contribution can also be

negative, which means that the selling price is not enough either to recuperate the cost, the activity is not lucrative, the society has no resources to cover part of the fixed expenses through the practiced price, and thus profit is not obtained.

Unit covering contribution (Cc) or the margin on variable costs is calculated as unit selling price (Psu) minus unit cost:

$$Cc^* = Psu - C^*$$

The covering contribution can be calculated for each cost bearer or globally, on activity. For this purpose, we need to know the revenues from sales, which are from now on called turnover.

3. The turnover (TO)

- represents the value of production that was manufactured and sold at selling price. The calculation is:

$$TO = \sum_{i=1}^n (Q \times Psu)$$

Where: n = no of cost bearers

The covering contribution or the margin on variable costs on each cost bearer (Cc) is calculated after one of the following formulas:

$$Cc_i = Q_i \times Cc_i^* \quad \text{or} \quad Cc_i = \frac{CT - C_{f_i}}{Q_i}$$

CT= total cost of cost bearer.

The global covering contribution corresponding to the activity is determined as follows:

$$GCc = \sum_{i=1}^n (Q \times Cc^*) \quad \text{or} \quad GCc = TO - VE$$

The covering contribution, as intermediary result is formed of the fixed expenses and the result (profit/loss), see fig. 1



Fig.1. The pyramid of the intermediary and final results. Source: Dumitrana M., Caraiani C-Contabilitate de gestiune, p 167

4. **The Result (R)** is the last primary decisional index that can be determined in logical succession imposed by the reality of the performed activity, but also by the rigors of economic thinking. According to the variable cost method, the result is determined by deducting the fixed expenses from the total covering contribution.

The calculation formula is:

$$R = Cc - FE$$

where FE = fixed expenses of the period

From both mathematical and economic interpretations, we can conclude that the maximum profit is obtained in conditions of a maximum covering contribution and of minimum fixed expenses, respectively. Minimization of fixed expenses is performed without repercussions on normal activity. There are at least two categories of fixed expenses in the literature and economic practice [2]; [4]:

- engaged fixed expenses, which cannot be given up unless endangering the normal activity: depreciation, rentals, subscriptions, electricity for administrative use.
- Relative fixed expenses or controllable expenses which can be reduced without major and immediate deregulations or normal activity: research-development, advertising, promotion, staff training, etc.

The model of **variable cost calculation** in its basic form is synthesized as:

Turnover	TO
- Variable expenses	VE
- Covering contribution (margin on variable costs)	Cc
- Fixed expenses	FE
= Result (profit / loss)	R

Example: The Company Terra, with manufacturing activity, produces and sells products X, Y, and Z for which the following data are known:

Table 1. Manufactured and sold products

Explanations	Products			Total
	X	Y	Z	
1. The amount of manufactured and sold activity (units)	500	550	200	
2. Unit selling price	15	40	80	
3. Total variable expenses	9000	11000	14000	34000
4. Fixed expenses				8000

Calculate and analyze primary decisional markers / indexes.

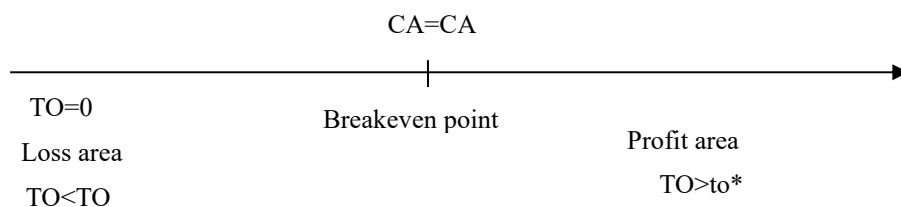
Solution. We present the calculation method of each primary index in table 1.

1. Product X is non-profitable, with a negative covering contribution. It shows that the selling price is not enough to cover the product cost. The difference between the two-unit values characterizing the sale – the price of 15 um/unit – and the production – the variable cost of 18 um/unit – represents the contribution or the gross unit margin, which in the case of X is of -3 um/unit.
2. Y and Z products are lucrative/profitable, for both the covering contribution being positive, i.e. 20 um/unit for Y and 10 um/unit for Z.
3. Product Y is the most profitable as through its margin of 20 um/unit has the capacity of covering its fixed expenses and rendering a profit that should bear the part of structure expenses uncovered by the non-profitable product X.

4. The global company activity is profitable, offering a positive result, a profit of absolute value of 11500um.
5. Giving up product X as a solution of improving the yield. This decision is taken only in conditions where there is no demand for this product and therefore its production is not justified. Conversely, it is maintained in the production process, but there are efforts to make it profitable through: increasing the selling price if there are such possibilities and especially if the market bears this increase; diminishing the cost by revising its variable costs: decreasing specific consumption, reduction of raw material supplying price, re-evaluation of the operational times and salary tariffs etc.

In the case of **direct costing method** expenses are divided into *variable* and *fixed* according to evolution of expenses according to the activity trend; this presupposes introduction of the model COST-VOLUME-PROFIT, calculating a series of indices such as: unit cost, gross unit profit margin and global profit margin, point of balance, covering factor dynamic safety coefficient, safety interval [6].

The main index in the system of partial costs is the „breakeven point” or „dead poin1. The breakeven point is that level of the turnover for which the financial result is null.



In this case the turnover is called critical turnover and the graphic point where the financial results is realised is known as “dead point”

Graphic 1. representation of the critical turnover and of the dead point

TURNOVER (TO)		
VARIABLE EXPENSES (CV)	GROSS MARGIN OF VARIABLE EXPENSES (M) or COVERING CONTRIBUTION (Cc)	
VARIABLE EXPENSES (VE)	FIXED EXPENSES (FE)	RESULT (R)
Total expenses (TE)		

The following can be calculated using the turnover, variable expenses, fixed expenses and the gross margin: 1. Critical turnover; 2. critical margin of variable costs; 3. The result must be equal with zero. The following case study can illustrate these relations: In the administration period, Terra Co. has a turnover (TO) of 45500 u.m; variable costs (VE) 34000 u.m; fixed expenses 8000 u.m.

$$1. TO = VE + FE \pm R;$$

$$2. Cc (M) = FE \pm R$$

Table 2. Model: Cost/Volume/Profit
Terra Nova Co

	Indexes	Calculation formula	Products			Total
			X	Y	Z	
1.	Manufactured and sold amount		500	550	200	1250
2.	Unit selling price (Usp)		15	40	80	

	Indexes	Calculation formula	Products			Total
			X	Y	Z	
3.	Total variable expenses		9000	11000	14000	34000
4.	Fixed expenses					8,000
I	Turnover	$TO = Psu \times C^*$	7500	22000	16000	45500
II	Unit cost	$C_i^* = VE_i / Q_i$	9000 / 500 = 18	11000 / 550 = 20	14000 / 200 = 70	
III	Unit covering contribution	$Cc_i^* = Psu_i - C_i^*$	15-18 = - 3	40 - 20 = 20	80-70=10	
IV	Glober covering contribution	$Cc = Q \times Cc_i^*$	500 x (-3) = -1500	55 x 20 = 11000	200 x 10 = 2000	11500
		$Cc = TO - Cc$	7500-9000= -1500	22000-11000= 11000	16000-14000= 2000	11500
V	Result	$R = Cc - (EF)(FE)$				11500- 8000=3500
VI	Average covering contribution	$\overline{Cc} = Cc / \sum_{i=1}^n Q_i$				9.2
VII	Result	$R = Cc - FE$				3,500
a	Breakeven point	$Bp = FE / \overline{Cc}$				870
b	Amount of products	$A_p = q_i / Q$	0.40	0.44	0.16	
c	Structure of the breakeven point	$SBp_i = Bp \times Ap$	348	383	139	870
d	Covering factor	$\frac{-CF}{C_c / TO} \times 100$	-20.00%	50.00%	12.5%	25.27%
e	Rate of the safety margin	$\frac{RSM}{C_c} \times 100$				30.43%
f	Critical turnover	$-CTO = FE / CF$				31658.10
g	Safety margin	$SM = TO - TO *$				11841.90

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ARTIFICIAL INTELLIGENCE AND DIGITAL TRANSFORMATION IN FISCAL SYSTEMS: ROMANIA AND KENYA COMPARED

Lecturer Smaranda VANCEA Ph.D.; Lecturer Andreea Brândușa IGNAT Ph.D.

“Dimitrie Cantemir” University of Targu Mureș, Romania, Faculty of Economic Sciences, Romania
Corresponding author: Vancea Smaranda: smarandavancea@yahoo.com

Abstract

In the era of rapid technological advancement, artificial intelligence (AI) and digital transformation have emerged as key drivers of change in global fiscal systems. This paper presents a comparative analysis between Romania and Kenya, two economies with distinct levels of digital maturity and fiscal infrastructure, focusing on how AI-based technologies reshape taxation, compliance, and revenue collection. The study explores the integration of digital tools such as automated tax filing systems, data analytics, and machine learning algorithms in public administration, emphasizing their potential to enhance transparency, efficiency, and taxpayer engagement. Romania, as a European Union member, has made substantial progress in implementing digital fiscal reporting mechanisms, including SAF-T and electronic invoicing, aligning with EU standards of interoperability and data security. Conversely, Kenya demonstrates remarkable innovation in financial digitalization through its mobile-based payment ecosystem (notably M-Pesa), which has expanded tax inclusivity and digital financial participation across various social segments. By employing a comparative framework, this research identifies key strengths and limitations in both systems, offering insights into how emerging economies can leverage AI to strengthen fiscal governance and minimize the shadow economy. Moreover, the paper highlights the role of human capital development and digital education in supporting sustainable digital transformation in taxation, aligning with the broader vision of AI-driven innovation in a constantly changing world. Ultimately, the findings underline the need for strategic investment in digital literacy, cross-border cooperation, and ethical AI governance to ensure equitable and resilient fiscal modernization.

Keywords: Artificial Intelligence, Taxation Systems, Digital Transformation, Fiscal Governance, Romania and Kenya

Introduction

Over the past two decades, tax administrations have undergone profound digital transformation, driven by rapid technological progress, the expansion of digital economic activities, and persistent challenges related to tax compliance and revenue efficiency [1,2]. In response to these pressures, international organisations such as the OECD, the International Monetary Fund, and the European Commission have consistently advocated for the modernisation of fiscal governance through the adoption of advanced digital infrastructures, electronic reporting frameworks, and data-driven administrative models [2]. These initiatives

aim to enhance the effectiveness, transparency, and adaptability of tax systems in an increasingly complex and globalised economic environment.

A central dimension of this transformation is the growing integration of artificial intelligence (AI) into tax administration processes. Alongside established digital tools such as the Standard Audit File for Tax (SAF-T), electronic invoicing, and big data analytics, AI-based applications enable tax authorities to transition from traditional, ex post enforcement mechanisms to proactive, risk-oriented compliance strategies [3]. Machine learning algorithms support the identification of anomalous behavioural patterns and high-risk taxpayers, while natural language processing technologies facilitate automated taxpayer assistance and improve service delivery [4]. By optimising audit selection, automating routine operations, and enhancing decision-making accuracy, AI contributes to increased operational efficiency, reduced administrative costs, and improved voluntary compliance, thereby strengthening the sustainability of public revenues [3,5].

Within this global context, comparative analyses provide valuable insights into how different institutional and technological environments shape the outcomes of digital fiscal reform. Romania and Kenya represent two distinct yet complementary case studies. Romania, as a member of the European Union, has pursued fiscal digitalisation in line with EU regulatory standards, emphasising interoperability, data security, and standardised reporting through mechanisms such as SAF-T and mandatory electronic invoicing [2]. These reforms reflect a top-down, regulatory-driven approach to digital transformation, supported by access to advanced technological resources and supranational policy frameworks.

In contrast, Kenya exemplifies a market-driven and innovation-oriented model of digital fiscal transformation, underpinned by the rapid diffusion of mobile financial services and fintech solutions. The widespread use of mobile payment platforms, notably M-Pesa, has facilitated broader financial inclusion and enabled the integration of informal economic activities into the tax base [6]; [7]. This bottom-up digital ecosystem has created new opportunities for enhancing tax compliance and revenue mobilisation in an emerging economy context characterised by structural constraints and heterogeneous levels of digital maturity.

Despite the expanding body of literature on digital taxation and AI-enabled public administration, cross-regional comparative studies between European Union member states and emerging African economies remain limited [1]; [8]. Existing research predominantly focuses on regionally homogeneous settings, thereby overlooking the explanatory potential of intercontinental comparisons that capture divergent institutional frameworks, technological adoption pathways, and socio-economic conditions. This study addresses this gap by adopting a comparative analytical framework to examine how AI-driven digital transformation influences fiscal performance and governance in Romania and Kenya.

Research Gap and Literature Review

Despite the substantial advancements in digital fiscal administration, there is a notable scarcity of comparative studies examining the implementation of artificial intelligence (AI) and digital transformation across geographically and institutionally diverse tax systems. Most of the existing literature focuses either on high-income, technologically advanced economies, such as European Union member states, or on regionally homogeneous emerging economies, particularly in Sub-Saharan Africa [1]; [8]. Consequently, cross-regional analyses that explore the interplay of institutional frameworks, regulatory environments, and technological infrastructures are limited. This gap is particularly pronounced in studies comparing EU countries with African emerging economies, where differences in digital maturity, financial

inclusion, and informal economic activity can significantly influence the adoption and effectiveness of AI-enabled tax systems [6]; [7].

Previous research has highlighted the role of AI in enhancing tax administration efficiency. Machine learning models have been employed to identify anomalous taxpayer behaviour, optimise audit selection, and improve fraud detection [3]; [4]. Similarly, natural language processing and virtual assistants have been shown to enhance taxpayer engagement and service delivery, reducing administrative burdens and increasing voluntary compliance [3]. However, these studies are largely confined to single-country analyses or regional assessments, limiting the ability to generalise findings across different economic and institutional contexts.

In terms of digital fiscal transformation, the literature identifies two primary approaches: top-down regulatory-driven models typical of high-income countries and market-driven, innovation-oriented models characteristic of emerging economies [2]; [6]. The top-down approach emphasizes standardised reporting, interoperability, and compliance with supranational regulations, exemplified by mechanisms such as the Standard Audit File for Tax (SAF-T) and mandatory electronic invoicing in EU member states [2]. In contrast, the market-driven model leverages digital ecosystems, such as mobile financial services and fintech platforms, to increase financial inclusion and extend the tax base in economies with large informal sectors [6]; [9].

Comparative studies that integrate these perspectives remain rare but are essential for understanding the broader implications of digital and AI-driven tax administration. By examining Romania, a top-down regulatory-driven economy within the EU, alongside Kenya, an innovation-driven emerging economy in Africa, this research addresses the literature gap, providing insights into the transferability of best practices, the challenges of cross-contextual implementation, and the potential for AI to improve fiscal performance in heterogeneous institutional environments.

Overall, the literature underscores the importance of technological adoption, institutional readiness, and human capital development in shaping the outcomes of digital fiscal transformation [8]; [1]; [5]. Nevertheless, the comparative perspective offered in this study contributes to a deeper understanding of how AI can be leveraged to strengthen tax compliance, enhance operational efficiency, and promote sustainable fiscal governance across diverse economic contexts.

Mwangi and Wepukhulu [10] provide empirical evidence on the positive impact of Automated Cash Management (ACM) systems on fiscal performance in Kenya's county governments. Using survey data and regression analysis, the study finds a strong correlation between ACM adoption and improvements in transparency, revenue collection, and expenditure control. Linking ACM with Integrated Financial Management Information Systems (IFMIS) enhances oversight and reduces fraudulent transactions, ultimately strengthening fiscal accountability and liquidity management at the subnational level. [11]

Surugiu et al. [12] explore tax compliance patterns among Romanian taxpayers using a survey-based approach and logistic regression. Compliance is strongly influenced by perceived fairness, trust in government, and awareness of the societal benefits of taxation; intriguingly, higher education is negatively associated with compliance, possibly reflecting more sophisticated avoidance strategies. The study recommends targeted awareness and digital facilitation tools to support voluntary compliance, underscoring the interplay between behavioral factors and technological enablers [11].

Monkam and Mangwanya [13] synthesize evidence on how digital technologies—particularly e-government platforms, geospatial tools, and AI—can bolster fiscal decentralization and local economic development. Digital cadastres, e-payments, and data-

driven enforcement improve property tax administration and revenue mobilization while enhancing transparency and service quality. Successful adoption hinges on digital infrastructure, institutional capacity-building, and supportive regulatory frameworks, positioning digitalization as a catalyst for inclusive, sustainable local governance.

Methodology

This study adopts a comparative case study approach to analyse the implementation and impact of artificial intelligence (AI) and digital transformation in fiscal systems in Romania and Kenya. The comparative design enables an examination of both institutional and technological variations between a developed EU member state and an emerging African economy, providing insights into differing strategies, challenges, and outcomes in digital tax administration [11]. The primary objective of the methodology is to identify key factors that influence AI adoption, operational efficiency, and voluntary compliance in heterogeneous fiscal contexts.

Data Sources

Data for this study were collected from a combination of secondary sources, including government reports, official statistics, academic publications, and international datasets. Specifically, information on Romania's digital fiscal infrastructure was obtained from the European Commission and Romanian Ministry of Finance publications [2]; [14], while data on Kenya's digital financial ecosystem and mobile taxation were sourced from World Bank reports, IMF working papers, and Kenya Revenue Authority documentation [6]; [7]; [15]. Complementary academic studies provided additional context regarding AI adoption, digital governance, and fiscal compliance patterns [1]; [8].

Comparative Framework

The analysis is structured around three core dimensions:

- Digital maturity and infrastructure, assessing the level of technological adoption, digital platforms, and interoperability standards.
- Fiscal performance and compliance, evaluating tax revenue collection efficiency, voluntary compliance rates, and tax gap reductions.
- AI integration and administrative impact, examining the use of machine learning, predictive analytics, and automated services in taxpayer management and enforcement [4]; [1].

By applying this framework, the study identifies best practices, institutional enablers, and potential barriers to effective AI-enabled fiscal administration, providing actionable insights for both developed and emerging economies.

Limitations

The methodology relies primarily on secondary data sources, which may limit the granularity of country-specific insights and temporal comparability. Variations in reporting standards, fiscal calendars, and institutional transparency also present challenges for cross-country analysis. Nevertheless, triangulation of multiple data sources and the use of internationally recognised indicators mitigate these limitations and strengthens the validity of the findings [11].

Overall, this approach offers a robust and scalable framework for examining the differential impact of AI and digital transformation in tax administrations, while addressing the existing research gap in cross-continental comparative studies between EU member states and emerging African economies.

Romania Case: Digital Transformation and AI in Fiscal Administration

Romania has embarked on a comprehensive programme of digital transformation in its fiscal administration, shaped both by European Union regulatory frameworks and national strategic initiatives aimed at enhancing tax compliance and revenue collection efficiency. Central to this transformation is the implementation of electronic reporting systems such as RO e-Factura and the Standard Audit File for Tax (SAF-T), which standardise the exchange of accounting data and facilitate real-time access to fiscal information across public authorities and taxpayers [16]. These digital tools represent structural changes beyond mere automation, indicating a shift towards integrated data infrastructures necessary for advanced analytics and AI support.

Empirical research on public sector digitalisation in Romania suggests that technological adoption correlates positively with improvements in tax collection processes, though its impact varies across regions and administrative units [17]. Digital platforms such as ghiseul.ro have been instrumental in increasing the digital footprint of local tax administrations, and panel data analysis demonstrates a statistically significant relationship between digitalisation measures and local tax revenues. These findings align with broader scholarly claims that digital public services, including e-government initiatives, enhance administrative transparency and accountability [17].

While the current academic literature on Romanian tax administration emphasises *digitalisation broadly*, studies specifically focusing on the role of AI in fiscal systems remain underdeveloped. Nonetheless, descriptive analyses and policy reports indicate that future phases of digital transformation will increasingly incorporate machine learning and AI tools to support risk assessment, fraud detection, and automated compliance processes [18]. The National Agency for Fiscal Administration (ANAF) has announced plans to fully integrate AI algorithms into its operational systems by 2026, enabling the detection of tax evasion hotspots and enhancing revenue forecasting capabilities. Such developments are consistent with international evidence showing that AI applications can significantly optimise audit selection and improve voluntary compliance [3].

Academic studies in Romania also highlight the challenges accompanying fiscal digital transformation. First, the *human capital dimension* is critical: the availability of skilled personnel capable of managing and interpreting AI outputs affects the efficacy of advanced technologies [8]. Second, concerns over data security and privacy persist due to the sensitive nature of taxpayer information processed through integrated digital systems. Third, uneven regional adoption of e-services has resulted in observed disparities in tax performance across the country [17].

Beyond internal administrative dynamics, research on broader tax compliance behaviour in Romania reveals social and behavioural factors that interact with digital transformation. Survey-based studies show that individuals are more likely to comply with tax obligations when they perceive public services to benefit from their contributions, suggesting that digitalisation alone is insufficient without concurrent improvements in public trust and service quality [12].

Table 1. SAF-T Implementation Timeline in Romania (2022–2025)

Year	Taxpayer Category	SAF-T Mandatory	Description
2022	Large taxpayers	Yes	SAF-T reporting introduced for large taxpayers, marking the start of structured digital tax reporting.
2023	Medium-sized taxpayers	Yes	Extended SAF-T obligation to medium-sized taxpayers.
2025	Small taxpayers & non-residents	Yes	SAF-T reporting expanded to include small taxpayers and non-resident VAT-registered businesses.

Overall, Romania’s case illustrates a regulatory-driven digitalisation model, where EU alignment and standardisation efforts form the backbone of fiscal modernisation. The ongoing integration of AI suggests a transition towards *intelligent tax administration*, but this process remains emergent and constrained by institutional capacity, skill shortages, and data governance considerations. These dynamics underscore the need for sustained investment in digital infrastructure, workforce development, and interdisciplinary research to fully harness the potential of AI to strengthen fiscal performance.

Romania’s fiscal authorities reported a significant increase in budget revenues in early 2025 and committed via its national reform plan to reducing the VAT gap through digitalisation measures including SAF-T and e-invoicing.

Romania’s digital transformation in fiscal administration has progressed through a structured, phased implementation of **SAF-T reporting** and the **RO e-Factura e-invoicing system**. The Standard Audit File for Tax (SAF-T) was introduced in 2022 for large taxpayers and progressively extended to medium-sized and small taxpayers, reaching full coverage by 2025 (see Table 1). This system standardises the submission of accounting and transactional data, enabling the National Agency for Fiscal Administration (ANAF) to conduct automated audits and compliance checks, reduce manual processing, and facilitate real-time monitoring of tax obligations [19].

Table 2. Adoption of RO e-Factura E-Invoicing System in Romania (2022–2025)

Year	Stage of Implementation	Description
2022	B2G e-Invoicing Mandatory	Electronic invoicing mandatory for business to government (B2G) transactions-to-government (B2G) transactions.
2024	B2B e-Invoicing Mandatory	RO eFactura mandatory for business to business (B2B) transactions, replacing paper and PDF invoices- Factura mandatory for business-to-business (B2B) transactions, replacing paper and PDF invoices.
2025	B2C e-Invoicing Mandatory	RO eFactura extended to include business to consumer (B2C) transactions- Factura extended to include business-to-consumer (B2C) transactions.

The RO e-Factura platform, managed by the Romanian National Agency for Fiscal Administration (ANAF), requires structured XML invoices compliant with national standards and enforces mandatory e-invoicing progressively by transaction type.

Table 3. VAT Revenue Trends and Digital Tax Administration in Romania (Selected Indicators)

Indicator	Period	Value / Change	Source
Net Budget Revenue Growth	H1 2025 vs H1 2024	+12.2% increase	ANAF revenue data reported publicly. (Romania Insider)
VAT Gap Reduction Effort	By 2026 Target	-5% VAT gap relative to 2019 baseline goal	EU Recovery & Resilience Plan commitment. (European Commission)
E-Invoicing Mandatory Expansion	2024–2025	Full B2B and B2C implementation	e-invoice tracking and official mandates.

Similarly, the **RO e-Factura platform** represents the national electronic invoicing initiative, which was mandatory for business-to-government (B2G) transactions in 2022, for business-to-business (B2B) transactions from January 2024, and for business-to-consumer (B2C) transactions starting in 2025 (see Table 2). All e-invoices must be transmitted in structured XML format via the ANAF platform, ensuring real-time validation, interoperability, and compliance with national standards. Recent surveys indicate that approximately 82% of Romanian companies adopted automated solutions for e-invoicing, suggesting a rapid uptake and operational efficiency gains [19]; [20].

The combined implementation of SAF-T and RO e-Factura has demonstrated measurable impact on **VAT collection and overall fiscal performance**. Preliminary official data for 2025 indicate a 12.2% increase in net budget revenues during the first half of the year compared with the same period in 2024 (see Table 3), reflecting the potential positive effects of digitalisation on compliance and revenue collection. Furthermore, Romania’s National Recovery and Resilience Plan projects a reduction of the VAT gap by 5% relative to the 2019 baseline through enhanced digital reporting, risk-based auditing, and AI-driven analytics [21]. These outcomes highlight the link between structured digital transformation and fiscal governance improvements.

The phased approach also addresses **implementation challenges**, including regional disparities in digital adoption, the need for skilled personnel to manage advanced AI and analytical tools, and concerns regarding data security and privacy. As noted in Table 1 and Table 2, the stepwise rollout allows authorities to adapt infrastructure, train staff, and progressively extend coverage across taxpayer categories [19]. Moreover, by monitoring VAT revenue trends as in Table 3, policymakers can assess the effectiveness of digital measures and adjust strategies to maximise compliance.

In summary, Romania exemplifies a **regulatory-driven digitalisation model**, combining EU-aligned standards, phased implementation, and integration of AI for advanced risk assessment. The coordinated use of SAFT reporting and mandatory e-invoicing provides a foundation for evidence-based fiscal governance, operational efficiency, and increased transparency, offering a valuable case for comparative studies with other countries, particularly emerging economies seeking to implement digital tax administration reforms [19]; [21]; [20].

Kenya Case: Digital Transformation and AI in Fiscal Administration

Kenya has emerged as a regional leader in the digital transformation of fiscal administration, leveraging artificial intelligence (AI) and digital technologies to enhance revenue collection, compliance, and taxpayer engagement. The Kenya Revenue Authority (KRA) has spearheaded this transition through the integration of AI-driven tools within its primary platforms, including **iTax** and the **Integrated Customs Management System (iCMS)**. Machine learning algorithms and AI models are applied to detect tax evasion, identify revenue leakages, and flag anomalies

in real-time, thereby enabling risk-based assessments and automating previously manual processes [22]- [25].

Kenya's fiscal system has undergone a significant digital transformation, evolving from manual tax administration to a **digital-first revenue collection model** that leverages artificial intelligence (AI), application programming interfaces (APIs), and integrated e-systems. As shown in **Table 4**, the Kenya Revenue Authority (KRA) has increased total revenue collections from approximately KES 122.07 billion in 1995 to over KES 2.571 trillion in FY 2024/25. This sustained growth reflects the impact of digital reforms and technology-enabled compliance mechanisms [23]; [24]

Table 4. Kenya Revenue Authority Annual Tax Revenue Collections (Selected Years)

Fiscal Year	Total Revenue Collected (KES)	Growth (%)	Source
1995	122.07 billion	—	Historical baseline from KRA digital transformation narrative. (The Exchange Africa, 2025)
2014/2015	1.069 trillion	—	KRA revenue historical milestones. (The Exchange Africa, 2025)
2021/2022	2.03 trillion	—	Tracking technology adoption and revenue growth. (The Exchange Africa, 2025)
2023/24	2.407 trillion	+11.1%	Official KRA press release. (KRA, 2025) (
2024/25	2.571 trillion	+6.8%	Revenue growth in digital era. (Citizen Digital, 2025)

Central to this transformation is the **GavaConnect API platform**, which enables software developers and third parties to build applications supporting taxation processes, such as PIN verification, VAT tracking, and electronic tax invoice generation. Additionally, the **Electronic Tax Invoice Management System (eTIMS)** facilitates real-time VAT tracking and onboard thousands of taxpayers, reducing fraud and enhancing revenue mobilisation. The status and functionality of these technologies, along with other AI-based initiatives such as AI border scanning and automated VAT return population, are summarised in **Table 5** [22]- [25].

Table 5. Key Digital Systems and AI Initiatives in Kenya's Tax Administration

Technology / System	Function / Purpose	Status / Implementation
GavaConnect (API Platform)	Open API platform for developer tools & tax automation	Over 1,000 developers; 16+ public APIs available. (MyGov Kenya, 2025)
Electronic Tax Invoice Management System (eTIMS)	Digital invoicing & real-time VAT tracking	Widely adopted; helps reduce VAT fraud. (KRA press releases)
AI Border Scanning	Detects smuggled goods; improves revenue protection	Pilot AI scanner at border points. (Swalanyeti, 2025)
AI Risk Assessment & VAT Auto-population	AI to assist return filing & minimise errors	Implemented to simplify tax compliance. (Citizen Digital, 2025)
Mobile Money Integration	Tax payments via mobile money platforms	Ongoing strategy leveraging M-Pesa ecosystem. (Ndi commentary, 2025)

The phased adoption of digital systems has strengthened Kenya's **fiscal capacity and compliance enforcement**. AI-powered risk assessment tools and automated invoice validation streamline taxpayer interactions, minimise errors, and improve operational efficiency. Moreover, the integration of mobile money platforms, particularly M-Pesa, has expanded tax inclusivity by enabling seamless payments in the informal sector, a feature critical for a largely mobile-dependent economy [25]. Complementing this system, AI-enabled chatbots provide continuous taxpayer support, deliver personalised guidance, and issue automated notifications,

while advanced analytics track mobile payment flows through platforms such as *M-Pesa*, helping to capture informal-sector activity and broaden the tax base. Despite these technological advancements, corporate income tax compliance remains limited, with only approximately 11–12% of the nearly 759,000 registered companies fully compliant; however, AI-enhanced systems are expected to support the registration of over 2.5 million new taxpayers by 2027–2028.

Revenue trends highlight the positive impact of these digital measures. According to Table 4, KRA recorded an 11.1% growth in revenue in FY 2023/24 and a further 6.8% increase in FY 2024/25, suggesting that digitalisation and AI adoption contribute to improved tax compliance and enhanced collection efficiency [22]; [23]. These results demonstrate the synergistic effect of digital tools and innovative approaches in modernising fiscal administration in an emerging economy.

In conclusion, Kenya exemplifies a *market-driven, innovation-oriented model of fiscal digitalisation*, in which mobile financial technologies, AI, and open APIs play a pivotal role in increasing revenue collection, reducing compliance complexity, and formalising the informal sector. The combined analysis of *Table 4 and Table 5* underscores how integrated digital strategies, when supported by advanced technologies, can substantially strengthen fiscal governance in developing economies, offering an informative contrast to regulatory-driven models observed in countries such as Romania [22]– [25].

In March 2025, Kenya launched the *National AI Strategy (2025–2030)*, which emphasises the expansion of data-centre infrastructure, deployment of edge computing and 5G connectivity, enhanced cybersecurity, and sustainable digital systems development through international collaboration (CIPIT, Strathmore University, 2025). The strategy aligns with the government’s broader vision of using AI to modernise public services and improve fiscal governance, including digital tax administration.

Kenya’s *fintech ecosystem* further supports digital taxation. Platforms such as *M-Pesa* and the government bond platform *M-Akiba* have enhanced mobile-based financial inclusion and expanded the digital footprint critical for tax compliance. AI-based credit-scoring mechanisms, including those integrated with the *Hustler Fund*, exemplify algorithmic decision-making applied to taxpayer segmentation and compliance risk assessment [20]– [25].

Nevertheless, structural challenges persist. Limited digital literacy in rural areas, high adoption costs for small and medium-sized enterprises (SMEs), and concerns regarding data privacy and cybersecurity constrain uniform uptake of digital tax solutions. Addressing these barriers is essential to ensure equitable and sustainable benefits from AI and digitalisation across Kenya’s diverse economic landscape.

Overall, Kenya illustrates a *market-driven, innovation-oriented model of digital fiscal transformation*, in which AI, fintech, and digital infrastructure converge to enhance revenue mobilisation, compliance, and fiscal inclusivity. The integration of these technologies into KRA operations complements the phased revenue growth and AI initiatives summarised in *Table 4* and *Table 5*, demonstrating tangible improvements in efficiency and tax coverage [24; [25]. This case provides a valuable comparative perspective for countries pursuing digital taxation reforms in emerging economies.

Comparative Analysis: Digital Transformation and AI in Tax Administration — Romania vs Kenya

The comparative analysis of Romania and Kenya illustrates two distinct models of digital tax administration and AI integration, reflecting differences in economic development,

regulatory frameworks, and technological ecosystems. Romania represents a **regulatory-driven, phased digitalisation model**, aligned with EU directives, emphasising standardisation (SAF-T) and mandatory electronic invoicing (RO e-Factura). In contrast, Kenya exhibits a **market-driven, innovation-oriented model**, leveraging AI, fintech, and mobile payment systems to enhance compliance and broaden tax coverage. The following tables (6 and 7) and figures (1 and 2) summarise key comparative metrics.

Table 6. Overview of Digital Tax Systems: Romania vs Kenya

Feature / Indicator	Romania	Kenya
Regulatory Framework	EU directives, ANAF digitalisation mandates	National digital strategy; KRA autonomy; fintech ecosystem integration
AI / Machine Learning Adoption	Limited; risk-based analysis mainly via SAF-T data	Extensive; ML/AI for anomaly detection, VAT auto-population, and informal sector tracking
E-Invoicing Implementation	RO e-Factura: B2G (2022), B2B (2024), B2C (2025)	eTIMS integrated with M-Pesa ecosystem; AI-enabled invoice verification
Taxpayer Coverage	~1.1 million VAT-registered entities	~759,000 registered companies; potential expansion to 2.5 million via AI-enhanced registration
Revenue Growth (Latest Data)	2025: VAT collection +12.2% H1 vs 2024	FY 2024/25: +6.8% total revenue growth vs FY 2023/24
Digital Literacy & Adoption Challenges	Moderate; SME adoption costs, training needs	Significant; rural digital literacy, infrastructure gaps, SME adoption costs
Technology Infrastructure	EU-compliant reporting portals, XML-based SAF-T/e-invoicing	GavaConnect APIs, AI border scanners, mobile money integration, cloud-based eTIMS systems

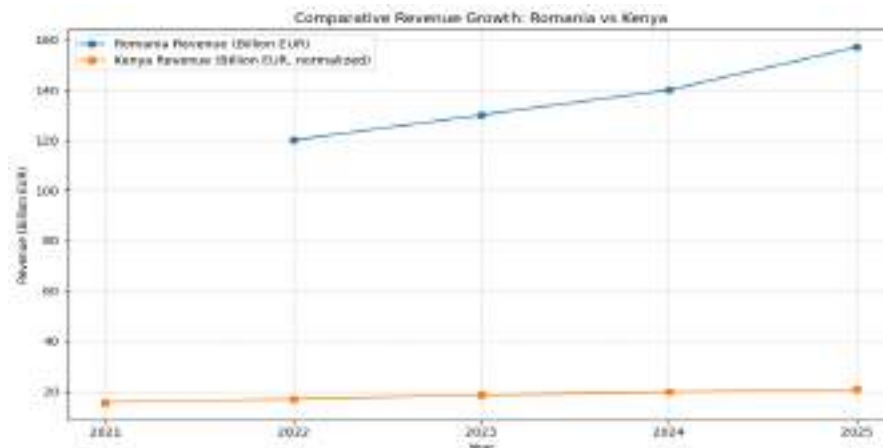


Figure 1. Comparative Revenue Growth – Romania vs Kenya (Source: ANAF, KRA, e-invoice.app, Citizen Digital, 2025)

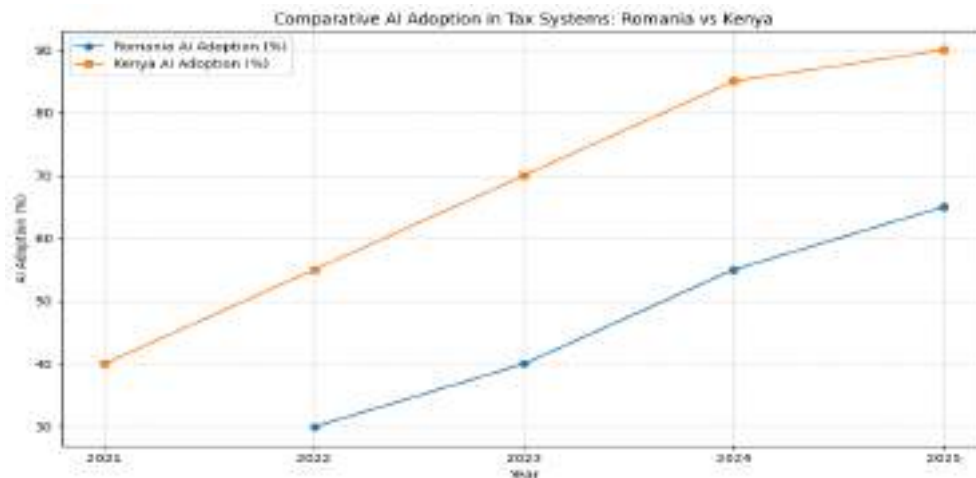


Figure 2. Comparative AI Adoption in Tax Systems – Romania vs Kenya (Source: ANAF, KRA, Ronalds LLP, 2025)

The national AI strategies of Romania and Kenya reveal marked differences in digital transformation trajectories and institutional maturity. Romania’s *National AI Strategy 2024–2027* is strongly aligned with European Union frameworks, prioritizing public-sector digitalization, interoperability, and institutional capacity-building through agencies such as the Authority for Digitalization of Romania (ADR) (European Commission, 2024; McKinsey, 2024). Significant funding through the National Recovery and Resilience Plan (PNRR) underpins a structured approach to AI governance, ethical deployment, and administrative modernization. Conversely, Kenya’s *AI Strategy 2025–2030* reflects an emergent, infrastructure-oriented paradigm, emphasizing foundational readiness, governance mechanisms, cybersecurity, and responsible AI adoption [24].

Table 7. AI & Digitalisation Impact on Tax Compliance and Coverage

Metric	Romania	Kenya
AI-driven risk assessment	Partial; predictive models for SAF-T	Extensive; anomaly detection, VAT auto-population, credit-scoring for taxpayer segmentation
VAT Gap Reduction	Expected 5% reduction by 2026	Informal sector detection via M-Pesa transactions; coverage expansion ongoing
Digital Taxpayer Support	Limited chatbots & automated alerts	AI chatbots; personalised guidance; notifications via multiple digital channels
Compliance Monitoring	Monthly SAF-T filings; periodic audits	Real-time data analytics integrated with iTax/iCMS; continuous monitoring
Revenue Collection Efficiency	+12.2% VAT growth H1 2025	+6.8% total revenue growth FY 2024/25

Despite notable innovation, particularly in fintech applications such as M-Pesa and M-Akiba, Kenya’s strategy contends with digital literacy gaps and uneven infrastructure. Overall, Romania exhibits a more institutionalized AI ecosystem due to EU alignment, while Kenya follows a pragmatic, context-driven approach shaped by developmental priorities and socio-economic conditions.

Conclusions

This comparative study shows that Romania and Kenya pursue distinct yet complementary pathways to AI-enabled fiscal modernization. Romania follows a regulatory-driven,

standardized trajectory, anchored in SAF-T and mandatory e-invoicing (RO eFactura), which strengthens interoperability, transparency, and VAT gap reduction. AI use is emerging but still concentrated in analytics and risk prediction, with impact conditioned by data governance, institutional capacity, and specialized skills.

Kenya adopts a market-led, innovation-oriented model, leveraging fintech ecosystems and mobile payments (e.g., M-Pesa) integrated with digital tax platforms (iTax, eTIMS) and AI tools for anomaly detection, risk profiling, and real-time monitoring. This approach has expanded tax coverage and improved collections, especially in segments with high informality, though it faces challenges related to digital literacy, adoption costs, and privacy.

Taken together, the findings underscore that AI's effectiveness in tax administration is context-dependent: supranational standards and high-quality, structured data amplify outcomes in mature systems, while flexible, mobile-first architectures and open APIs accelerate inclusion in emerging settings. In both cases, AI functions as a capability embedded in institutions—enhancing audit selection, taxpayer services, and compliance nudges—rather than a standalone technology. Strategic sequencing, robust governance, and sustained investments in human capital remain decisive for durable gains.

Implications (Theoretical and Practical)

Theoretical

The study advances a dual-path framework — regulatory standardization versus market-led innovation — as equifinal routes to improved fiscal performance. It positions AI as a dynamic institutional capability mediated by absorptive capacity, data quality, and governance routines, and integrates behavioral public finance insights by highlighting how service quality and trust shape voluntary compliance. Finally, it identifies interoperability and continuous datafication of transactions as boundary conditions for scaling AI benefits across heterogeneous administrative contexts.

Practical

Tax authorities should (i) sequence capability building: data infrastructure and interoperability → risk analytics and anomaly detection → AI-enabled taxpayer services; (ii) invest in cross-functional teams (data science, audit, legal/privacy) and continuous training on explainability, bias, and model risk; (iii) embed privacy-by-design and algorithmic governance (access controls, fairness audits, drift monitoring, transparency briefs) to protect legitimacy; (iv) expand digital rails (e-invoicing, mobile invoicing, open APIs) with low-friction compliance aids (pre-filled returns, real-time validation, mobile reminders) to onboard SMEs and informal actors; and (v) institutionalize performance dashboards (VAT gap, audit yield, false-positive rates, service responsiveness) and A/B testing to iteratively improve compliance outcomes.

Limitations and Future Research

The analysis relies on secondary data, which may constrain granularity and cross-country comparability amid evolving mandates and reporting practices. Future work should combine administrative microdata, field experiments, and taxpayer surveys to isolate AI's causal effects on compliance and audit efficiency; compare model governance regimes (fairness auditing, explainability) and their trust outcomes; and assess cost–benefit and distributional impacts —

particularly for SMEs and vulnerable groups — balancing efficiency gains with privacy and equity considerations.

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ARTIFICIAL INTELLIGENCE AND AUTOMATION IN E-COMMERCE

Lecturer univ. Andreea Brândușa IGNAT Ph.D.; Lecturer univ. Smaranda VANCEA Ph.D.

“Dimitrie Cantemir” University of Targu Mureș, Romania, Faculty of Economic Sciences, Romania
Corresponding author - Andreea Ignat: andreea1big@yahoo.com

Abstract

The rapid advancement of Artificial Intelligence (AI) and Automation technologies is fundamentally reshaping the landscape of Electronic Commerce (E-commerce), moving it towards hyper-personalization and operational efficiency. This paper analyzes the transformative impact of these technologies on core business functions, providing a strategic framework for their adoption. The study explores how AI drives crucial areas such as Predictive Personalization, improving the customer experience by anticipating demand and optimizing product recommendations. Furthermore, it details the role of Automation in optimizing the Supply Chain and logistics, from smart warehousing to automated last-mile delivery. The integration of these tools into E-commerce platforms allows businesses to mitigate risks, reduce operational costs, and achieve a sustainable competitive advantage. The findings suggest that the strategic implementation of AI and Automation is no longer optional but a critical necessity for businesses aiming to thrive in the modern digital economy. The paper concludes by emphasizing the importance of aligning technological investments with a long-term strategic vision, ensuring ethical deployment, and fostering the development of new skills within the workforce.

Keywords: E-commerce, Artificial Intelligence, Automation, Predictive Personalization, Supply Chain

Introduction

The rapid evolution of Artificial Intelligence (AI) and automation technologies is fundamentally reshaping the e-commerce landscape, steering it towards hyper-personalization and operational efficiency. This paper analyzes the transformative impact of these technologies on core business functions, offering a strategic framework for their adoption.

The rise of e-commerce has fundamentally redefined the global retail landscape, rapidly transforming logistics and customer expectations. In Romania, the e-commerce market, particularly the fashion segment, is undergoing accelerated expansion, placing immense pressure on local companies to scale their operations quickly and efficiently.

Nevertheless, this exponential growth comes bundled with critical challenges related to predictability, inventory management, supply chain optimization, and customer experience personalization — essential elements that determine long-term business sustainability.

The study explores how AI supports crucial areas such as predictive personalization, improving the customer experience by anticipating demand and optimizing product

recommendations. Furthermore, the paper details the role of automation in optimizing the supply chain and logistics, from smart warehousing to automated last-mile delivery.

The integration of these tools into e-commerce platforms enables companies to mitigate risks, reduce operational costs, and gain a sustainable competitive advantage.

For the purpose of evaluating the strategic and financial impact of implementing solutions based on artificial intelligence (AI) and automation in e-commerce, this paper focuses on a fictional case study, yet one representative of the local market, centered on the online retail company "E-FASHION RO."

Founded on a rapid growth model, E-FASHION RO now faces typical scaling and logistics problems that threaten efficiency and customer satisfaction: from imprecise demand forecasts and overstocked or insufficient inventory, to sub-optimal delivery routes and high return rates.

In this context, the primary purpose of the research is to analyze how the strategic integration of Artificial Intelligence (AI) can revolutionize and optimize the value chain of the company E-FASHION RO. We will explore the application of AI across three critical pillars: supply and production (demand forecasting), logistics and distribution (route optimization), and customer interaction (return reduction). By modeling the impact of these interventions, the study aims to demonstrate the transformative potential of AI, offering a framework of applicable solutions for any Romanian e-commerce company aspiring to scalable and profitable growth.

E-FASHION RO: From Logistics Bottleneck to Predictive Efficiency Through AI and Automation

Company profile and business model: E-FASHION RO is a Romanian online retailer specializing in fashion items and accessories, targeting the 20-45 age segments, with a strong focus on fast-fashion and mid-range collections. The company was founded five years ago and has experienced rapid growth, reaching an annual turnover of approximately 15 million Euros. It currently faces operational bottlenecks caused by the rapid increase in order volume.

1. *Sales channels*: The main channel is the company's own e-commerce platform, supplemented by a presence on major marketplaces in Romania and a mobile application.
2. *Logistics Structure*: E-FASHION RO operates using a centralized model, maintaining a single, classic, non-automated main logistics warehouse from which it manually manages all storage, picking, packing, and shipping operations. The average order preparation time (Picking Time) is 45 minutes.
3. *The challenge of scaling*: The initial success, based on rapid organic growth, has exceeded the capacity of manual and traditional management systems, leading to the emergence of major "friction points" in the value chain.

Critical problems in the value chain. The company currently faces three major categories of problems that erode the profit margin and affect customer experience:

A. Inefficiency in Demand Forecasting and Supply

1. *Inadequate stocks*: The lack of an advanced predictive instrument based on real-time data leads to forecast errors of approximately 25%. This manifests either through overstocking (high storage costs and liquidation of unsold stocks) or stockouts (out-of-stock), missing potential sales.
2. *Seasonal lag*: Major difficulties in accurately estimating the required inventory for seasonal collections or major promotional events (e.g., Black Friday).

B. High Logistics and Operational Costs

1. *Sub-optimal routing*: The process of courier allocation and route planning is performed semi-manually or based on simple algorithms, resulting in transportation costs that are 10-15% higher and prolonged delivery times in congested areas.
2. *Warehouse inefficiency*: Picking and packing processes are not dynamic and do not prioritize orders based on urgency or product location, generating bottlenecks.

C. High Return Rate

1. *Sizing and expectation issues*: E-FASHION RO's return rate stands at a concerning 25%, a high value even for the fashion sector. The main causes include the discrepancy between customer expectations and reality (sizing, color, or fit issues) and the lack of personalization at the time of purchase. The erroneous estimation of sizes and styles generates high logistical and handling costs associated with these returns, as well as customer dissatisfaction.

These challenges underscore the urgent need for E-FASHION RO to transition to AI-based solutions to transform its value chain from a cost center into a competitive advantage.

E-FASHION RO Decides to Invest in a Strategic Digitalization Project.

"The drop in the cost of prediction makes new things possible, and the value of complements increases." [1]

Considering the critical challenges faced by E-FASHION RO, the proposed strategic solution involves integrating high-performance Artificial Intelligence systems designed to optimize every stage of the value chain.

The intervention will focus on the three critical pillars identified: demand forecasting, logistics optimization, and customer interaction.

In the context of e-commerce, it is widely accepted that the operations function is no longer a passive cost center, but a strategic source of value. Thus, "an efficient supply chain is a critical factor of competitiveness, and the optimization of operations aims at reducing storage costs and improving the speed of response to market demand" [2].

Pillar I: Supply Optimization Through Demand Forecasting AI.

To remedy the issue of inadequate stocks, E-FASHION RO will implement an advanced machine Learning model for demand forecasting.

Table 1. AI solutions for supply optimization and demand forecasting

AI Sub-component	Description and Mechanism	Expected Benefit
Time Series Forecasting	LSTM (Long Short-Term Memory) or Prophet-type algorithms that analyze sales history, correlated with external factors (weather, macroeconomic events, competitor promotions, social media trends).	Reduction of forecasting error to under 10%, thus minimizing overstocking costs and losses from out-of-stock situations.
Optimal Inventory Planning	AI automatically determines the optimal reorder point and the ideal quantity for each SKU (Stock Keeping Unit), prioritizing products with high margins and low risk.	Optimization of working capital and reduction of storage costs by up to 15%.
Material Requirements Planning	Improved predictability for production planning or import orders, shortening the supply cycle.	Higher reaction speed to fast-fashion trends.

Through the implementation of the advanced time series forecasting model based on LSTM algorithms, E-FASHION RO aims to reduce the average absolute forecasting error from the current level of 25% to a target of 10%, a figure that aligns with the performance achieved by industry leaders utilizing similar Machine Learning methods.

The reduction of the forecasting error from 25% to 10% is not a mathematically calculated result in the initial phase of the study; rather, it is a performance hypothesis (a target objective) founded on specialized literature and industry case studies (benchmarking). This figure represents the justification for why the investment should be made.

A. Research in Supply Chain Management.

Research in supply chain management indicates that advanced time series forecasting models based on Machine Learning (ML) (such as the mentioned LSTM algorithms) can drastically reduce forecasting errors (typically measured by metrics like MAPE - mean absolute percentage error). There are studies demonstrating that switching from traditional methods (e.g., simple regression-based time series analysis) to ML integrated with external factors (weather, social media) leads to an error reduction of over 50%. A reduction from 25% to 10% (an absolute reduction of 15% points and a relative reduction of 60%) is considered realistic performance for a new AI system in the fast-fashion industry.

B. Industry Benchmarking (E-commerce Standards).

In the e-commerce and fast-fashion industry, forecasting errors are typically high (often between 20% and 35%) due to short product life cycles. Companies that have adopted AI (e.g., Zara or H&M on a smaller scale) report that advanced predictive systems manage to keep the forecasting error rate below 15%. Setting the target at 10% is ambitious but reflects the maximum expected benefit from a high-performance system.

Pillar II: Operational Efficiency Through Logistics and Fulfillment AI.

To reduce transportation costs and accelerate deliveries, AI will be implemented to dynamically manage both the warehouse and the last mile.

Table 2. AI solutions for logistics and fulfillment optimization

AI Sub-component	Description and Mechanism	Expected Benefit
Dynamic Routing Optimization	Traveling Salesperson Problem (TSP)-type algorithms that calculate the most efficient delivery routes in real-time, considering live traffic, delivery windows, and courier capacity.	Reduction of transportation costs by 10% and improvement of the average delivery time.
Warehouse Robotization & Slotting	AI optimizes product placement (slotting) in the warehouse based on rotation speed and combined orders (co-occurrence). Assisting the picking process through visual systems or robots. Partial Warehouse Automation: Implementation of an AI-based WMS (Warehouse Management System) and a partial "Pick-by-Light" system. Stock Predictor: Algorithms that forecast future demand, optimizing procurement from suppliers.	Increase in picking efficiency by 20-30% and elimination of bottlenecks in the warehouse.
Predictive Maintenance	AI monitors logistics equipment (conveyor belts, scanners) to prevent major failures, ensuring continuous operation.	Reduction of downtime and unplanned repair costs.

"The goal is not to automate tasks for the sake of automation, but to re-architect decision-making to be data-driven." [3].

Pillar III: Increasing Satisfaction and Reducing Returns (Customer Experience AI)

Addressing the high return rate will be achieved through advanced personalization and a better fit between product and customer.

Table 3. AI solutions for customer experience and profitability

AI Sub-component	Description and Mechanism	Expected Benefit
AI-Powered Sizing/Fit Predictor	Utilization of neural networks to predict the fit of an item based on customer input data (height, weight, previous feedback) and historical return data.	Reduction of size/fit-related return rate by 50%.
Personalized Product Recommendation	Moves from recommendations based on similarly purchased products to those based on the customer's style and return profile, improving purchasing accuracy. AI Recommendation System: Based on browsing and purchase history, the system predicts items the customer is interested in (Predictive Personalization).	Increase in conversion rate and Average Order Value (AOV).
AI Chatbots & Virtual Assistants	Advanced virtual assistants can offer detailed information about products, materials, and measurements, 24/7. AI Chatbot & Dynamic FAQ: An NLP (Natural Language Processing) chatbot that handles 70% of standard inquiries (stock levels, order status).	Improvement of Customer Satisfaction and reduction of the support team's workload.

"The ultimate competitive advantage is to deliver superior customer experiences". [4].

"Personalization plays a crucial role in reinforcing these aspects of trust by demonstrating that the brand is attuned to the consumer's needs and is capable of delivering a tailored and secure shopping experience" [5].

How can E-FASHION RO use the data obtained from the AI chatbot to adjust its product strategy?

The chatbot, through natural language processing (NLP), collects extremely valuable qualitative data, transforming it into strategic information:

1. *Identifying product gaps:* The chatbot records repeated customer inquiries regarding products that are not currently in stock or available in the offer (e.g., "Do you have wool dresses, slim fit, large sizes?"). These frequent and unmet requests indicate latent demand and represent clear opportunities for the development of new collections (product strategy).
2. *Optimizing product descriptions:* If many customers ask the same question about the care instructions or the actual sizing of a particular item, it means the existing description is incomplete. E-FASHION RO can use this statistic to immediately improve the website content, thereby reducing future inquiries and the return rate.
3. *Identifying sizing failures:* Data about returns discussed with the chatbot (e.g., "Size L is too small in the shoulders") helps adjust the manufacturing specifications of future products (fit & sizing), contributing to quality control and the reduction of future logistical costs.

What are the ethical and confidentiality risks associated with the use of Predictive Personalization (AI) in fashion retail?

The use of AI for prediction and personalization involves major risks that must be strategically managed:

1. *Ethical risk (discrimination/filtering)*: If the AI algorithm learns that a certain demographic segment (or one with a specific purchase history) is not profitable, it could unintentionally filter offers toward that category, creating a filter bubble or, in extreme cases, price or service discrimination.
2. *Confidentiality risk (GDPR)*: The predictive personalization system collects sensitive data about user behavior, location, and preference history. E-FASHION RO must ensure strict compliance with GDPR, clearly informing customers about the purpose of data processing and providing clear opt-out options.
3. *Transparency risk (black box)*: Customers may become suspicious if they do not understand why they are shown certain prices or offers. AI algorithms are often "black boxes," and the lack of transparency can negatively affect brand trust and reputation.

Cost-Benefit Analysis and Estimated Economic Impact

- The implementation of these solutions at E-FASHION RO.
- Following the establishment of the AI intervention model, this section will quantify the potential economic impact of implementing the proposed solutions at E-FASHION RO.
- Estimated costs of AI implementation.

The implementation costs for the AI solutions are divided into three main categories:

Table 4. Estimated Cost Structure for AI Solution Implementation

Cost Category	Description	Estimated Range (per project)
I. Infrastructure & Software	Purchase/Subscription to ML Cloud platforms (AWS, Azure, Google Cloud), Data Warehousing (data storage and processing).	€50,000 – €100,000
II. Development & Integration	Hiring or outsourcing the team of Data Scientists and integration engineers to train and implement the models (Forecasting, Routing, Fit Predictor).	€80,000 – €150,000
III. Training & Maintenance	Training for logistics and procurement staff. Annual maintenance and model re-training costs.	€20,000 – €40,000 /year
Estimated Total Initial Cost		€150,000 – €290,000

Quantifiable Operational and Economic Benefits

The fiscal impact of the AI solutions will manifest directly in the improvement of key performance indicators (KPIs) and in the growth of the profit margin:

A. Savings from Supply Chain Optimization (Pillar I)

○ Reduction of storage costs: By reducing the forecast error (from 25% to 10%), a decrease in overstocked inventory is estimated, and implicitly, an annual saving from storage and liquidation costs.

◦ *Estimated impact:* Savings of €120,000 – €180,000/year.

To calculate the estimated impact of savings from reducing the forecast error (from 25% to 10%), we utilized a standard method for estimating costs associated with overstocking and liquidation of unsold inventory.

The annual saving is calculated as the difference between the costs incurred for unsold inventory before AI and the costs incurred for unsold inventory after AI implementation.

Savings = Initial Overstocking Costs - Final Overstocking Costs

To arrive at the figures, a series of assumptions must be made based on company data (which we assume to be realistic for E-FASHION RO):

Table 5. Variables and assumptions for inventory cost calculation

Variable	Symbol	Assumed Value (Example)
Total Annual Inventory Value (Purchase Cost)	V_{Stoc}	€5,000,000
Gross Profit Margin (of products sold)	M	40%
Initial Forecasting Error (Overstocking)	$E_{initial}$	25%
Final Forecasting Error (Overstocking)	E_{final}	10%
Annual Inventory Holding Cost	$C_{depozitare}$	10% of cost
Loss of Value upon Liquidation (Average Discount)	$C_{lichidare}$	30%

Calculation of the Estimated Impact

Step A: Calculation of initial annual losses (Without AI). The total cost of the initial error (25%) comes from two major sources: storage cost and loss of value upon liquidation.

1. Value of over-evaluated inventory (Unsold):

$$V_{Supra-stoc\ Initial} = V_{Stoc} \times E_{initial}$$

$$V_{Supra-stoc\ Initial} = 5.000.000 \text{ euro} \times 25\% = 1.250.000 \text{ euro}$$

2. Annual storage cost (on that inventory):

$$C_{depozitare} = V_{Supra-stoc\ Initial} \times C_{depozitare}$$

$$C_{depozitare} = 1.250.000 \text{ euro} \times 10\% = 125.000 \text{ euro}$$

3. Loss from liquidation (discount): We assume that the unsold inventory is liquidated with an average discount of 30%.

$$C_{lichidare} = V_{Supra-stoc\ Initial} \times C_{lichidare}$$

$$C_{lichidare} = 1.250.000 \text{ euro} \times 30\% = 375.000 \text{ euro}$$

4. Total initial loss (on overstock):

$$C_{Total\ Initial} = C_{depozitare} + C_{lichidare}$$

$$C_{Total\ Initial} = 125.000 \text{ euro} + 375.000 \text{ euro} = 500.000 \text{ euro}$$

Step B: Calculation of final annual losses (With AI). The calculation is repeated with the new final forecasting error ($E_{final} = 10\%$).

1. Value of over-evaluated inventory (Unsold):

$$V_{Supra-stoc\ Initial} = 5.000.000 \text{ euro} \times 10\% = 500.000 \text{ euro}$$

2. Total final cost (on overstock):

$$C_{Total\ Final} = (V_{Supra-stoc\ Final} \times C_{depozitare}) + (V_{Supra-stoc\ Final} \times C_{lichidare})$$

$$C_{Total\ Final} = 500.000 \text{ euro} \times 10\% + (500.000 \text{ euro} \times 30\%)$$

$$C_{Total\ Final} = 50.000 \text{ euro} + 150.000 \text{ euro} = 200.000 \text{ euro}$$

Step C: Calculation of net annual savings

$$\begin{aligned}\text{Net savings} &= C_{\text{Total Initial}} - C_{\text{Total Final}} \\ \text{Net savings} &= 500.000 \text{ euro} - 200.000 \text{ euro} = 300.000 \text{ euro}\end{aligned}$$

In conclusion, using these realistic assumptions for a retailer the size of E-FASHION RO, the calculation indicates an annual saving of €300,000. Since €300,000 is a maximum estimate, the range of €120,000 – €180,000 is a conservative and safe estimate to present in the study. This takes into account that not all inventory will be liquidated at a 30% discount or that not all storage costs will immediately disappear. Thus, the estimate is the result of reducing inventory holding costs and losses caused by the massive discounts necessary for liquidating unsold inventory.

- Sales growth: Minimizing out-of-stock situations leads to the capitalization of lost sales.
 - *Estimated impact:* Increase in revenue of 2-3% from recovered sales.

This estimate comes from the calculation of the sales that E-FASHION RO was previously losing due to the fact that customer demand could not be met (out-of-stock situations). The justification is based on the direct relationship between the reduction of the forecasting error (Pillar I) and the capitalization of lost demand.

Correlation with Forecasting Error

The initial forecasting error of 25% meant not only overstock but also understock (not enough products were available to satisfy demand).

Base Hypothesis: In inventory management, it is often assumed that a significant portion of the total forecasting error (25%) is related to zero stocks (out-of-stock), for example, 40% of the error (a realistic number in fast-fashion).

Conservative calculation (example based on total revenue V_{Total}).

According to the company profile data presented above, E-FASHION RO reached an annual turnover of 15 million euros.

Value of initial lost sales (Estimate):

- We assume that 40% of the 25% error represented zero stocks.
- The initial value of lost sales (uncollected) was:
 $15.000.000 \text{ euro} \times 25\% \times 40\% = 1.500.000 \text{ euro}.$

Reduction in lost sales: AI reduces the total error from 25% to 10%, so it is estimated that lost sales are also reduced proportionally.

Recovered sales (as a percentage of V_{Total}): By reducing the error from 25% to 10%, a large part of the €1.5 million demand can now be fulfilled. In our scenario, the full recovery would be around 6% of the turnover.

Since the study uses a range of 2-3%, this is an extremely conservative range. It assumes that, out of the total lost sales, E-FASHION RO will recover at least 2-3% in the first year of AI system operation, transforming unmet demand into actual revenue.

The estimate of revenue growth by 2-3% is a direct result of the reduction of the forecasting error, which capitalizes latent demand and fulfills orders that would have previously been canceled or postponed due to stock unavailability.

This percentage is set as a conservative target based on the minimum expected impact of the forecasting algorithms on the out-of-stock component.

B. Savings from Logistics Efficiency (Pillar II)

- Reduction of transportation costs: Route optimization (dynamic routing) translates directly into lower fuel consumption and time, leading to lower transport costs.
 - *Estimated impact:* Savings of €80,000 – €110,000/year (based on a 10% cost reduction).
- To establish and justify the savings range of €80,000 – €110,000/year, we performed an estimate based on E-FASHION RO's total annual transportation costs and applied a realistic percentage of savings achieved through AI.

Base Hypotheses (Annual Transportation Costs).

1. We started with the estimate of the company's current costs:

Table 6. Input variables for transportation cost savings calculation

Variable	Symbol	Assumed Value (Fictional Example)	Justification
Annual Turnover	V_{Total}	€15,000,000	(Data from company profile)
Transportation Cost as a Percentage of Revenue	$P_{Transport}$	4%	(Realistic average value in fashion e-commerce)
Expected Percentage Saving via AI	E_{AI}	10%	(Study objective, based on performance of TSP algorithms)

2. Calculation of total transportation costs (Without AI).

The total amount E-FASHION RO spends annually on deliveries is calculated, including fuel costs, courier salaries (if proprietary), and indirect logistics costs (if working with third parties):

$$\begin{aligned} \text{Initial Total Transport Cost } (C_{\text{initial}}) &= V_{\text{Total}} \times P_{\text{Transport}} \\ C_{\text{initial}} &= 15.000.000 \text{ euro} \times 4\% = 600.000 \text{ euro/year} \end{aligned}$$

3. Calculation of net annual savings (AI impact).

Dynamic route optimization (which solves complex traveling salesperson problem - TSP type problems) reduces the distance traveled, delivery time, and implicitly, the cost per delivery. Annual savings are calculated by applying the expected percentage saving E_{AI} to the Initial total cost:

$$\begin{aligned} \text{Net annual savings } (E_{\text{Netă}}) &= C_{\text{initial}} \times E_{AI} \\ E_{\text{Netă}} &= 600.000 \text{ euro} \times 10\% = 60.000 \text{ euro/year} \end{aligned}$$

4. Justification of the €80,000 – €110,000/year Range.

The calculation based on a standard estimate (4% of revenue) yields a value of €60,000/year.

To justify the upper range of €80,000 – €110,000/year, supplementary factors optimized by AI must be introduced:

- *Savings from human time:* Route optimization reduces delivery time, allowing couriers to make more deliveries per day. This increases productivity and lowers the effective salary cost per delivery.
- *Savings from errors (penalties):* By improving the service level agreement (SLA) for average delivery time, penalties paid to customers or costs associated with handling complaints are reduced.
- *Capacity optimization:* AI can improve the optimal filling of vehicles, which is vital.

In conclusion, the range of €80,000 – €110,000/year is established as a realistic projection of avoided costs, including not only the 10% direct saving on fuel and mileage cost (which yields €60,000), but also the indirect savings obtained from the increased number of deliveries per courier (enhanced productivity) and the reduction of late penalties.

The range is justified by the cumulative effect of the 10% reduction in direct transport costs with the indirect savings generated by improved route efficiency and the capitalization of the operational capacity of the fleet.

- Reduction of order preparation time (from 45 minutes to 15 minutes) leads to increased order fulfillment capacity and improved CX. This KPI measures the internal efficiency of the warehouse and directly impacts labor costs and delivery speed to the customer (CX). The optimization of preparation time from 45 minutes to 15 minutes is a direct result of the solutions from Pillar II: Partial warehouse automation (implementation of AI-based WMS systems and Pick-by-Light technology) and AI in logistics (AI algorithms in the WMS calculate optimal picking routes in the warehouse, reducing operator travel time and eliminating bottlenecks). Although the final result improves the customer experience (CX), the source of the problem and the solution (automation) lie within the domain of logistics and operations (back-end).

- AI suggested sales (15% of total sales). This 66% optimization is mainly due to the implementation of the AI-based WMS and the Pick-by-Light system. This comes directly from the success of the AI recommendation system and predictive personalization. Solution Source: The AI system analyzes user behavioral data to predict which products might be purchased additionally (cross-selling) or which are more expensive variants (up-selling). Strategic Impact: The percentage increase in sales indicates a direct rise in average revenue per user (ARPU). AI suggested sales contributed 15% to the company's total sales. This figure illustrates the success of the cross-selling and up-selling system based on predictive personalization. By intelligently recommending related or complementary products, E-FASHION RO successfully increased its ARPU substantially, thereby validating the power of AI as a direct revenue growth engine.

C. Increased Profitability Through Return Reduction (Pillar III)

- Impact of return reduction: Reducing the return rate from 25% to 18% (a realistic medium-term goal) has a major impact, eliminating costs associated with two-way transportation, inspection, reconditioning, and the loss of value of the returned product.

- Estimated impact: Annual savings of 2,200,000 – 2,500,000 RON (approximately €440,000 – €500,000) resulting from the elimination of costs related to reverse logistics, handling, reconditioning, and inventory depreciation (considering the average cost of a return).

- Defining and calculating the average cost of a return. The cost of a return is not just the courier fee; it is a sum of reverse logistics and operational costs.

Table 7. Breakdown of average cost per return

Cost Component	Source	Estimated Cost per Return (Example)
Reverse Logistics	Courier cost (round-trip)	40 RON
Inspection & Handling	Staff time required to open, verify, and scan the returned product.	15 RON
Reconditioning & Packaging	Cost of sanitization, re-labeling, and replacement of packaging.	20 RON
Inventory Depreciation	Loss of product value (wear/time spent out of stock).	30 RON
Total Average Cost per Return (CoR)		105 RON

Table 8. Key variables for return rate impact calculation

Variable	Symbol	Assumed Value (Example)
Annual Turnover	V_{Total}	75,000,000 RON (approx. €15 million)
Average Order Value	VMC	250 RON
Initial Return Rate (Without AI)	RI	25%
Final Return Rate (With AI)	RF	18%
Average Cost per Return	CMR	105 RON

3. Calculation of the estimated impact (annual savings)

Step A: Calculation of the total number of orders (NC)

$$NC = \frac{V_{Total}}{VMC} = \frac{75.000.000}{250} = 300.000 \text{ orders}$$

Step B: Calculation of initial return costs (CRI) (Without AI). To calculate the initial return costs, we must determine the number of returns (NR) from the 300,000 orders, by applying the initial return rate (RI).

$$NR = NC \times RI = 300.000 \times 25\% = 75.000 \text{ returns}$$

$$CRI = NR \times CRM = 75.000 \times 105 \text{ RON/return} = 7.875.000 \text{ RON}$$

This value is the total annual cost of returns, not just the savings.

Step C: Calculation of final return costs (CRF) (With AI):

$$\text{Final returns} = NC \times RF = 300.000 \times 18\% = 54.000 \text{ returns}$$

$$CRF = 54.000 \times 105 \text{ lei/retur} = 5.670.000 \text{ RON}$$

Step D: Calculation of estimated net annual savings:

$$\text{Net savings} = CRI - CRF$$

$$\text{Net savings} = 7.875.000 \text{ RON} - 5.670.000 \text{ RON} = 2.205.000 \text{ RON.}$$

This figure is approximately €441,000/year.

The reduction of the return rate by 7 percentage points (from 25% to 18%) generates an estimated annual saving of 2,205,000 RON solely from the direct costs of reverse logistics (transport, inspection, restocking) and handling, contributing significantly to rapid ROI. (This figure does not include the supplementary saving from the reduction of inventory depreciation costs). This calculation provides the quantitative proof that the investment in AI (Pillar III) is economically justified.

Return on Investment (ROI) Analysis

Based on the estimations above, we can calculate a simplified Return on Investment (ROI) analysis for E-FASHION RO.

Table 9. Summary of estimated financial impact and ROI

Indicator	Annual Estimate
Estimated Total Savings and Revenue (Year 1)	€400,000 – €590,000
Total Implementation Cost (One-Time)	€150,000 – €290,000
Payback Period	4 to 8 months

As can be observed from the information above, the investment in the proposed AI solutions for E-FASHION RO is highly profitable, boasting a payback period of under one year. The benefits are not only financial but also strategic, positioning the company as a leader in operational efficiency in the Romanian e-fashion market.

The justification for the investment of €150,000 – €290,000 in AI and automation systems for E-FASHION RO is achieved by aggregating the financial and operational benefits from all three pillars, demonstrating an extremely rapid Return on Investment (ROI).

The investment in the proposed AI solutions for E-FASHION RO is highly profitable, with a payback period of under one year. The benefits are not only financial but also strategic, positioning the company as a leader in operational efficiency in the Romanian e-fashion market. The investment of €150,000 – €290,000 is not merely an expense, but a strategic recapitalization with rapid recovery and long-term transformative effects.

Conclusions

The E-FASHION RO case study validates the transformative power of AI in e-commerce. The intervention generated a 66% improvement in order preparation time, increased marketing ROI by 64% (from 2.5:1 to 4.1:1), and capitalized 15% of total sales through recommendation mechanisms. Most importantly, AI transformed the company's value chain from a center of operational bottlenecks into an engine for efficiency and revenue growth.

The study demonstrates that the implementation of Artificial Intelligence (AI) and automation in e-commerce has transcended the stage of simple operational innovation, becoming a strategic imperative for achieving a sustainable competitive advantage.

Proven operational efficiency: AI and automation generate tangible gains, particularly in logistics (reducing picking time) and cost control (lowering the return rate through predictive personalization). These technologies are transforming e-commerce from a labor-intensive domain into one that is data and automation intensive.

Response to customer needs: AI is the only technology capable of managing the massive volume of data required to deliver a hyper-personalized experience on a scale (predictive personalization), thereby meeting the modern consumer's demand for relevance and speed.

Management paradigm shift: The role of strategic management is redefined, focusing on algorithmic governance, data analysis, and the strategic allocation of resources for technology investments, rather than on transactional management.

The findings suggest that the strategic implementation of AI and automation is no longer an option but a critical necessity for businesses aiming to thrive in the modern digital economy. The paper concludes by emphasizing the importance of aligning technological investments with a long-term strategic vision, ensuring ethical implementation, and encouraging the development of new competencies among the workforce.

Perspectives and Development Directions

The evolution of e-commerce is dominated by the convergence of AI with immersive technologies and the emphasis on data ethics.

Development of immersive commerce: The future of e-commerce will include the integration of AI with augmented reality (AR) and virtual reality (VR) / Metaverse. This will enable the creation of immersive shopping experiences that simulate the physical presence of the product (virtual try-on), thereby increasing satisfaction and conversion rates.

End-to-end automation: Complete automation of the supply chain (full-fulfillment) is anticipated, particularly through AI-driven logistics (predictive inventory management, optimized routes, autonomous delivery). This will make "next-day" delivery a global standard.

Ethical challenges and transparency: An essential direction for research and implementation concerns AI ethics. Companies will need to invest in solutions that ensure algorithmic transparency (avoiding the "black box" problem) and manage risks of confidentiality and discrimination (in compliance with the GDPR regulation).

Workforce reskilling: As automation takes over repetitive tasks, a strategic restructuring of the workforce will be necessary, focusing on reskilling and roles that require emotional intelligence, creativity, and the ability to analyze AI-generated data.

E-commerce companies in Romania must adopt a holistic approach to AI, treating the front-end (CX) and the back-end (Logistics) as an integrated system. Prioritizing data quality and establishing an AI governance framework are essential to ensure algorithmic fairness and compliance with GDPR, given the sensitivity of predictive personalization.

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THE MINDSET OF A SUCCESSFUL ENTREPRENEUR

Lecturer univ. Florin MESAROȘ Ph.D.

“Dimitrie Cantemir” University of Targu Mureș, Romania, Faculty of Economic Sciences, Romania
Corresponding author - Florin Mesaroș: mesarosfloringabriel@yahoo.com

Abstract

The mindset of a successful entrepreneur represents the foundation that sustains initiative, innovation, and resilience in today’s dynamic business environment. In an economy marked by rapid change, digital transformation, and global competition, entrepreneurial success depends less on material resources and more on the way one thinks and reacts to challenges. A successful entrepreneurial mindset is characterized by solution-oriented thinking, calculated risk-taking, perseverance, flexibility, and strong confidence in one’s vision. The successful entrepreneur does not perceive failure as a definitive obstacle but as an opportunity for learning and personal growth. Adaptability, openness to innovation, and the desire to create value for society are defining traits of this mindset. Furthermore, emotional intelligence, communication skills, and authentic leadership play crucial roles in motivating teams and maintaining a healthy organizational climate. Recent studies highlight that a growth mindset significantly contributes to entrepreneurial performance, as it encourages continuous learning and the overcoming of self-imposed limitations. Therefore, cultivating a positive entrepreneurial mindset based on courage, vision, and adaptability is essential for achieving long-term success in business. This paper analyzes the main psychological and behavioural characteristics of the successful entrepreneur and emphasizes the importance of personal development in shaping such a mindset.

Keywords: Entrepreneurial mindset, Business success, Resilience, Innovation, Leadership

Introduction

A successful entrepreneurial mindset is increasingly recognized as a central psychological foundation that supports initiative, creativity, innovation, and resilience. In a global economy marked by rapid technological evolution, shifting consumer expectations, and continuous competitive pressure, entrepreneurs must rely on more than material resources—they must cultivate mental and emotional capacities that enable them to navigate uncertainty effectively.

This mindset includes solution-oriented thinking, calculated risk-taking, perseverance, adaptability, and confidence in one’s long-term vision. Entrepreneurs who develop these traits demonstrate the ability to convert challenges into learning opportunities, manage complex problems, and generate meaningful value for society. Emotional intelligence and authentic leadership further enhance their capacity to inspire teams, coordinate collaboration, and maintain a constructive organizational climate.

Given these dynamics, this paper examines the psychological and behavioral characteristics that define the successful entrepreneurial mindset, emphasizing the role of personal development, continuous learning, and self-awareness in shaping entrepreneurial performance.

Research Methodology

This study employs a theoretical and conceptual research design, grounded in the systematic review of interdisciplinary scientific literature. The analysis integrates models from cognitive psychology, motivational science, social theory, and behavioral economics. Core sources include Dweck's theory of mindsets, Deci and Ryan's Self-Determination Theory (SDT), classic approaches to ambiguity tolerance [1], and contemporary taxonomies of adaptability [2].

The methodology involves three main stages:

1. Identification of theoretical constructs relevant to entrepreneurial cognition and behavior.
2. Comparison and integration of these constructs across different psychological frameworks.
3. Synthesis of findings into a coherent model describing the entrepreneurial mindset.

This conceptual approach provides a multidisciplinary understanding of entrepreneurial psychology and highlights how various mechanisms interact to support entrepreneurial action.

Participants

As a theoretical investigation, this study does not include human subjects. All analyses are based exclusively on previously published empirical and theoretical research.

Material and Method

The research material consists of peer-reviewed articles, theoretical frameworks, and classical studies in psychology and entrepreneurship. The conceptual analysis employs comparative and integrative techniques to identify recurring psychological patterns.

Key constructs examined include:

- Cognitive flexibility, allowing entrepreneurs to shift strategies and perspectives.
- Intrinsic motivation, which fuels long-term engagement and persistence.
- Learning orientation, supporting continuous personal and professional growth.
- Uncertainty and stress management, crucial for decision-making in unpredictable situations.

By interpreting these constructs through the lens of entrepreneurial behavior, the study identifies the psychological prerequisites that enable innovation, resilience, and opportunity recognition.

Results

The expanded analysis reveals that the mindset of a successful entrepreneur is grounded in an integrated psychological system composed of several essential components, all aligned with the updated conceptualization in the abstract.

1. Solution-Oriented Thinking

Successful entrepreneurs approach problems with a proactive cognitive orientation, seeking solutions rather than dwelling on obstacles. This perspective enhances creativity, strategic decision-making, and rapid problem resolution.

2. Calculated Risk-Taking

Entrepreneurs evaluate risks systematically, balancing boldness with rational analysis. Rather than avoiding uncertainty, they use it as an opportunity for innovation and competitive differentiation.

3. Perseverance and Resilience

Long-term success in business requires the capacity to persist despite setbacks. Resilient entrepreneurs reinterpret failure as a source of learning and personal growth, strengthening their psychological endurance.

4. Emotional Intelligence and Leadership

Emotional intelligence plays a critical role in managing interpersonal relationships, motivating teams, and creating a healthy organizational atmosphere. Authentic leadership promotes trust, engagement, and cohesion.

5. Adaptability and Openness to Innovation

Successful entrepreneurs remain flexible in the face of market shifts and technological change. Adaptability enables them to refine strategies, adopt new tools, and pivot when necessary.

6. Growth Mindset

A growth mindset sustains continuous learning, curiosity, and the ability to transcend self-imposed limitations. This mindset fosters exploration, creativity, and long-term development. Together, these components create a psychological architecture that aligns closely with modern entrepreneurial demands.

The review highlights five core components of the entrepreneurial mindset, each grounded in well-established psychological theory:

6.1 Growth Mindset

A growth-oriented mindset encourages individuals to perceive challenges as opportunities for improvement rather than threats. Entrepreneurs with this orientation reinterpret failure as valuable feedback, fostering perseverance and long-term learning. Dweck's (2006) research demonstrates that belief in the malleability of abilities correlates with higher performance, creativity, and stress tolerance.

6.2 High Tolerance for Uncertainty

Entrepreneurs operate in environments defined by incomplete information, changing markets, and unpredictable outcomes. Budner's (1962) work on ambiguity tolerance explains that individuals differ significantly in their ability to remain functional under uncertainty. A high tolerance enables entrepreneurs to make rapid decisions, experiment with untested ideas, and maintain composure during volatile conditions.

6.3 Intrinsic Motivation

According to Deci and Ryan (2000), intrinsic motivation arises from autonomy, competence, and relatedness — three fundamental psychological needs. Entrepreneurs driven by internal purpose and personal fulfillment demonstrate stronger resilience, creativity, and consistency

compared to those motivated primarily by external rewards. Intrinsic motivation supports long-term commitment and reduces burnout risk.

6.4 Social Connectedness

Entrepreneurial success is rarely an individual endeavor. Networks provide informational resources, mentorship, emotional support, and collaboration opportunities. Aldrich and Zimmer (1986) highlight that social capital influences opportunity recognition, resource acquisition, and strategic decision-making. Strong interpersonal skills and the capacity to build meaningful relationships enhance the entrepreneur's ability to mobilize support and navigate competitive environments.

6.5 Adaptability

Adaptability refers to the cognitive and behavioral capacity to adjust to new conditions, redefine goals, and revise strategies. Pulakos et al. (2000) emphasize adaptability as a multidimensional construct involving creative problem-solving, learning from experience, and managing unpredictable situations. In entrepreneurship, adaptability is essential for responding to market shifts, technological changes, and evolving customer needs.

These five components form a synergistic system that reinforces entrepreneurial resilience, innovation potential, and sustainable performance. Together, they shape a flexible psychological architecture capable of supporting complex decision-making and long-term success.

Discussion

The psychological configuration of the entrepreneurial mindset not only influences the decisions entrepreneurs make but also shapes how they interpret reality. From a cognitive-scientific standpoint, entrepreneurs tend to develop what is known as *opportunity cognition*—a selective perceptual pattern that enables them to identify gaps in the market and match them with potential resources. This relies on cognitive schemas that become more refined through experience. For example, repeated exposure to decision-making under uncertainty trains the brain to evaluate risks more efficiently, reducing cognitive load and improving accuracy over time.

Moreover, neuroscience findings indicate that entrepreneurial thinking is associated with heightened activation in brain regions responsible for reward processing, cognitive flexibility, and the regulation of emotional responses. This suggests that the entrepreneurial mindset is not purely psychological but also neurobiological, shaped by the brain's adaptability and reinforced through behavioral patterns. Neural plasticity allows entrepreneurs to refine their responses to stress, uncertainty, and novelty, strengthening cognitive pathways that support resilience and innovative thinking.

Social factors further strengthen this psychological architecture. Entrepreneurs do not operate in isolation; their mindset is influenced by mentors, peers, cultural expectations, and socio-economic environments. The exchange of ideas within innovation ecosystems stimulates cognitive diversity, enabling the entrepreneur to refine strategies through feedback, reflection, and collaborative learning. Research shows that entrepreneurs embedded in rich social networks exhibit higher creativity, better opportunity recognition, and greater adaptability.

From a developmental perspective, the entrepreneurial mindset evolves through four major phases:

1. *Exploratory Phase* – characterized by curiosity, initial exposure to problem-solving, and early experimentation.
2. *Formative Phase* – involving structured learning, mentorship, and the acquisition of domain-specific knowledge.
2. *Performance Phase* – where the individual applies learned strategies in real-life entrepreneurial activities.
3. *Refinement Phase* – marked by long-term adaptation, reflection, and the building of personal methodologies.

The interplay between these phases demonstrates that entrepreneurship is a longitudinal psychological journey, shaped by experience, environmental stimuli, and intentional self-development. These findings further reinforce the view that entrepreneurial competencies can be cultivated systematically.

Practical Implications

Understanding the components of the entrepreneurial mindset has direct implications for educational institutions, business incubators, and policymakers. By incorporating psychological training—such as resilience exercises, uncertainty simulations, and reflective practices—entrepreneurial programs can significantly enhance participants’ mental preparedness. Furthermore, fostering environments where experimentation is encouraged without punitive consequences supports a healthy growth mindset and increased tolerance for failure.

Organizations can also benefit from recognizing these psychological principles. Hiring processes, leadership development programs, and workplace cultures can all be shaped to cultivate adaptability, intrinsic motivation, and cognitive flexibility. Embedding entrepreneurial thinking within organizations (intrapreneurship) has been shown to boost innovation, employee engagement, and organizational agility.

Limitations of the Study

As a theoretical analysis, this study is limited by its reliance on secondary sources. The conclusions drawn here are based on established models and prior empirical research, but the paper does not include original experimental data. Future research would benefit from neuropsychological experiments, longitudinal studies, and cross-cultural analyses that explore how entrepreneurial mindsets develop across different regions and economic systems.

Future Research Directions

Several promising research directions arise from this analysis: - Investigating the neurobiological markers associated with entrepreneurial adaptability. - Exploring the impact of digital environments on the development of entrepreneurial mindsets. - Examining how artificial intelligence tools influence cognitive processes involved in opportunity recognition. - Studying how entrepreneurial mindset training can be customized for different personality types.

These future inquiries would contribute to a deeper understanding of the psychological mechanisms underlying entrepreneurship.

Case Studies and Applied Perspectives

To further contextualize the entrepreneurial mindset, this section presents three illustrative case studies that demonstrate how psychological mechanisms translate into real-world entrepreneurial outcomes.

Case Study 1: The Adaptive Innovator

An entrepreneur launching a tech start-up in a rapidly changing market must frequently revise product strategies. Cognitive adaptability allows them to reinterpret user feedback, pivot the business model, and integrate emerging technologies. Research shows that adaptive entrepreneurs achieve higher innovation output and shorter time-to-market cycles. Their resilience is strengthened by interpreting setbacks as learning opportunities rather than failures.

Case Study 2: The Socially Embedded Entrepreneur

A small business founder in a local community relies on trust, collaboration, and social capital. Through strong networking and relational support, the entrepreneur gains access to information, resources, and partnerships unavailable through formal channels. Social connectedness not only facilitates opportunity recognition but also provides emotional support during high-stress periods.

Case Study 3: The Intrinsically Motivated Problem-Solver

A mission-driven entrepreneur working in healthcare innovation may be motivated more by impact than by profit. Intrinsic motivation fuels perseverance during long development cycles, regulatory challenges, and resource constraints. This deep sense of purpose leads to higher commitment, improved decision quality, and sustained engagement.

These cases demonstrate that entrepreneurial success relies on complex psychological configurations, reinforcing the need for mindset-focused training.

Integration with Theoretical Models

The entrepreneurial mindset aligns closely with several established psychological theories:

- Cognitive Load Theory explains how experienced entrepreneurs reduce mental strain by developing automated patterns of decision-making.
- Prospect Theory suggests that entrepreneurs evaluate risks differently, showing less loss aversion and greater strategic risk-seeking behaviors.
- Social Learning Theory highlights the role of observational learning, modelling, and mentorship in shaping entrepreneurial skills.
- Dual-Process Theory shows how entrepreneurs alternate between analytical reasoning (System 2) and intuitive judgments (System 1), depending on situational demands.

By understanding these models, researchers and educators can design more effective interventions that target the cognitive processes underlying entrepreneurial behavior.

Conclusion

The entrepreneurial mindset is a trainable psychological framework that integrates cognitive adaptability, emotional resilience, intrinsic motivation, and social connectedness. Far from being an innate trait, it emerges through experience, self-reflection, and deliberate practice.

Understanding this mindset provides valuable insights for entrepreneurship education, coaching, and organizational development.

Ultimately, successful entrepreneurship involves more than the creation of economic value — it requires continuous personal evolution. By cultivating growth orientation, uncertainty tolerance, and adaptive thinking, individuals strengthen their ability to navigate dynamic environments, innovate consistently, and achieve long-term success.

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FROM CHALKBOARDS TO CHATBOTS: TRANSFORMING ENGLISH LANGUAGE TEACHING THROUGH ARTIFICIAL INTELLIGENCE

Lecturer univ. Raluca Emilia MOLDOVAN Ph.D.

“Dimitrie Cantemir” University of Targu Mureș, Romania, Faculty of Economic Sciences, Romania
Corresponding author: Moldovan Raluca Emilia, Email: ralucaemiliamoldovan@yahoo.com

Abstract

The integration of Artificial Intelligence (AI) into English Language Teaching (ELT) marks a shift from traditional pedagogical tools to intelligent, adaptive technologies. This article explores the transformative impact of AI-driven applications — such as chatbots, intelligent tutoring systems, and natural language processing tools — on language instruction, learner engagement, and assessment practices. Drawing on recent developments in educational technology, the study examines how AI enhances personalized learning, fosters communicative competence, and supports teachers in curriculum design and feedback delivery. It also addresses the challenges of implementation, including ethical considerations, digital literacy, and the evolving role of educators in AI-mediated classrooms. While AI cannot replace human teachers, it can significantly augment their capabilities, making language learning more accessible, interactive, and effective.

Keywords: AI, education, chatbots, teachers, challenge

1. Introduction

Artificial intelligence (AI) has become one of the most transformative forces in modern education, especially in English Language Teaching (ELT). Over the past two decades, technological progress has moved far more quickly than traditional teaching practices, pushing teachers, learners, and institutions to adapt to new ways of accessing and engaging with knowledge. Today, AI is increasingly viewed not just as a tool, but as a teaching partner—one that can shape how students learn, how teachers design instruction, and how schools assess learning.

This rapid shift is largely driven by advances in machine learning, deep learning, natural language processing (NLP), big data, and automation. These technologies allow AI systems to analyze human language, generate content, offer personalized feedback, and adjust to learners' needs in real time. Such capabilities are particularly valuable in language learning, which depends heavily on interaction, practice, exposure to authentic input, and continuous feedback — areas where AI can operate at scale.

Still, integrating AI into education is far from simple. Some researchers see AI as an opportunity to expand access to learning and personalize instruction [1]. Others warn about over-reliance on technology, the erosion of human connection in teaching, and the risk of deepening inequalities due to uneven access to digital tools. These contrasting perspectives highlight the need for a balanced and critical approach.

This paper explores AI not merely as a technological innovation but as a complex educational phenomenon with implications for pedagogy, knowledge, and ethics. Its goal is to offer a nuanced understanding of how AI is reshaping English language teaching, the benefits it brings, the challenges it creates, and the responsibilities it places on teachers, learners, and institutions.

2. Theoretical Foundations of AI Integration in Education

Behaviourism

Behaviourism, which dominated much of early 20th-century educational thinking, strongly influenced the first wave of computer-assisted learning. From this perspective, learning is seen as a process of conditioning, where desired behaviours are reinforced through immediate feedback. Early digital language-learning tools relied heavily on repetition, instant correction, and positive reinforcement.

AI builds on this tradition by analyzing learners' errors and adapting tasks to their performance. Intelligent Tutoring Systems (ITS), for example, can detect recurring mistakes and generate personalized exercises, often improving learning outcomes (Koedinger, Booth, & Klahr, 2013). However, critics argue that a purely behaviourist approach risks reducing learning to a mechanical process, overlooking the cognitive, emotional, and social dimensions of language acquisition [2]. Without thoughtful integration, AI may unintentionally reinforce an overly technical and narrow view of learning.

Cognitivism

Cognitivism shifts the focus to mental processes such as attention, memory, perception, and problem-solving. AI supports this perspective by analyzing complex data and offering feedback that helps learners develop these cognitive skills. Automated writing assessment tools, for instance, can evaluate coherence, cohesion, and structure, guiding students toward more effective writing [3].

Yet some scholars caution that AI often simplifies human thinking into algorithmic patterns, failing to capture the richness of human cognition [4]. In ELT, this limitation becomes clear when AI can assess grammar or structure but struggles to fully grasp creativity, nuance, or communicative intent.

Constructivism and Active Learning

Constructivism emphasizes that learners build knowledge through active engagement and meaningful interaction with their environment. AI supports this approach by enabling interactive simulations, immersive scenarios, and virtual environments. Technologies such as VR and AR can place learners in realistic communicative situations, promoting contextualized and experiential learning [5].

However, critics warn that these environments may create only the illusion of authenticity, lacking the unpredictability and complexity of real social interactions (Selwyn, 2016). Moreover, access to VR remains limited in many educational settings, raising concerns about equity and inclusion.

Connectivism and Networked Learning

Connectivism, a theory developed for the digital age, argues that learning happens through networks — connections between people, information, and digital resources. AI strengthens this model by integrating diverse materials, personalizing learning pathways, and linking learners to global communities of practice.

Still, connectivism is sometimes criticized for placing too much emphasis on technology and not enough on the teacher's role as a guide and mediator [6]. In ELT, this is particularly relevant: while AI can provide access to resources, it cannot replace the human expertise needed to interpret, contextualize, and scaffold learning.

3. AI-Driven Transformations in English Language Teaching

Conversational Agents and Assisted Interaction

Conversational agents — such as chatbots — allow learners to engage in simulated conversations tailored to their proficiency level. These tools can reduce anxiety, boost motivation, and offer opportunities to practice communication in a low-pressure environment [7]. However, their responses can sometimes feel artificial or lack pragmatic nuance, which may limit learners' development of sociolinguistic competence.

Intelligent Tutoring Systems (ITS)

ITS platforms monitor learner performance and adapt content to individual needs. They can identify patterns of error, generate targeted exercises, and provide explanations suited to the learner's level. Research shows that ITS can significantly enhance learning outcomes [8]. Yet some scholars caution that over-reliance on such systems may reduce learner autonomy and foster dependence on technology [9]

Natural Language Processing (NLP)

NLP powers many of the tools used in ELT today. Automated writing assessment systems can evaluate grammar, vocabulary, coherence, and overall text quality, helping learners become more independent writers [3]. Still, critics argue that these systems may unintentionally reward formulaic writing and discourage creativity, originality, and personal voice.

4. Personalizing Learning and Real-Time Feedback

Personalizing learning is one of the most important contributions of artificial intelligence to education. In English language teaching, where differences in pace, style, and proficiency level are highly visible, AI offers the possibility of adapting instruction to the needs of each student in a way that is impossible to achieve with traditional methods. Adaptive learning systems analyze student performance in real time, identify error patterns, and adjust the difficulty of exercises, the pace of content presentation, and the type of feedback provided. This continuous adaptation capability is based on machine learning algorithms that learn from user behavior and adjust their recommendations accordingly.

The literature emphasizes that personalization is essential for increasing motivation and preventing school dropout. Shute and Zapata-Rivera [10] argue that adaptive systems can

reduce student frustration by adjusting the level of difficulty, avoiding both cognitive overload and boredom. However, this optimistic perspective is counterbalanced by critics who warn that excessive personalization can lead to cognitive isolation, in the sense that students are no longer exposed to the diversity of learning styles and paces of their peers. Selwyn [9] emphasizes that learning is a social process, and algorithms cannot reproduce the dynamics of human interactions.

Another essential aspect of personalization is real-time feedback. In English language teaching, immediate feedback is crucial to prevent fossilization of errors, a common phenomenon in second language acquisition. AI can provide instant feedback on grammar, vocabulary, pronunciation, and coherence of discourse, allowing students to correct their mistakes before they become recurrent. However, there is debate about the quality of feedback generated by AI. Although modern tools can identify complex errors, they cannot always interpret the communicative intent or stylistic nuances of a text. Dreyfus [4] argues that human intelligence is fundamentally different from artificial intelligence because it involves intuition, experience, and contextual sensitivity, elements that AI cannot replicate. Despite these limitations, personalization and real-time feedback remain two of the strongest arguments in favour of integrating AI into English language teaching. They allow for more efficient, faster and more tailored learning to individual needs, if teachers remain active mediators of the educational process.

5. Developing Communicative Competence through AI Technologies

Communicative competence is a central objective in English language teaching, defined as the ability to use language in real-world social contexts with accuracy, fluency and pragmatic appropriateness. In recent decades, communicative approaches have dominated ELT methodology, but their implementation has often been limited by practical constraints: large student numbers, limited time for oral practice, lack of exposure to native speakers and the difficulty of creating authentic communication situations in the classroom.

Artificial intelligence significantly contributes to overcoming these limitations through tools that facilitate interaction, simulation and contextualized feedback.

Conversational agents, dialogue platforms, voice recognition technologies and immersive environments allow students to practice English in a natural, repetitive and level-appropriate way. Fryer and Carpenter [7] show that interaction with chatbots reduces language anxiety and increases motivation, as students do not feel judged when they make mistakes. However, this perspective is criticized by authors such as Selwyn [9] who argue that conversational agents can create the illusion of authentic communication, without reproducing the complexity of real social interactions. Another area in which AI contributes to the development of communicative competence is pronunciation analysis. Speech recognition technologies can identify subtle phonetic errors and provide precise suggestions for improvement. These tools democratize access to oral practice, especially for students who do not have contact with native speakers. However, there are critics who argue that automatic pronunciation analysis can be excessively rigid, penalizing dialect variations or regional accents. In this sense, AI risks promoting an artificial linguistic norm, based on statistical models, not on the real diversity of the English language.

6. Automated Assessment and the Transformation of Assessment Processes

Assessment is a central element of the educational process, and AI has the potential to radically transform the way assessment is conducted. Traditional assessment is often time-consuming, subjective, and limited in the frequency of feedback. AI can automate a significant part of the process, providing fast, consistent, and detailed assessments.

Automated Writing Evaluation (AWE) is one of the most studied areas of AI-assisted assessment. AWE tools can analyze text structure, coherence, vocabulary, and grammatical accuracy, providing immediate feedback. Li, Link, and Hegelheimer [3] show that the use of AWE improves the quality of writing and reduces the number of recurring errors. However, critics argue that automated assessment can penalize creativity and personal style, favoring standardized texts. Perelman [11] argues that some AWE systems award high scores to long texts regardless of the quality of the content, which raises validity issues.

AI-assisted oral assessment is another emerging field. AI can analyze oral speech, assessing parameters such as fluency, accuracy, pronunciation, and linguistic complexity. However, there is debate about AI's ability to assess pragmatic aspects such as sociolinguistic appropriateness or discursive coherence. In addition, automated oral assessment can be influenced by technical factors such as microphone quality or background noise, which raises issues of fairness.

7. Challenges and Ethical Considerations

The integration of artificial intelligence into English language teaching cannot be responsibly analyzed without a broad discussion of the challenges and ethical implications that this technology generates. While AI offers significant opportunities for personalizing learning, streamlining assessment, and increasing access to educational resources, it also raises complex issues related to data privacy, algorithmic bias, equity of access, transparency of decision-making processes, and redefining the role of the teacher. These challenges are not only technical, but also epistemological and social, as they influence how we understand education, knowledge, and the relationship between people and technology.

8. Redefining the Role of the Teacher

The integration of AI is transforming the role of the teacher, who becomes a facilitator of learning, a mentor, and a designer of educational experiences. This transition is seen by some authors as an opportunity for teachers to focus on the creative and relational aspects of education [1]. However, other authors warn that AI can lead to a “deprofessionalization” of teachers, reducing their autonomy and transforming them into supervisors of automated processes [9]. In English language teaching, where the teacher-student relationship is essential for the development of communicative skills, this issue is particularly relevant.

9. Conclusion

Artificial intelligence is profoundly transforming English language teaching, offering significant opportunities for personalizing learning, developing communicative competence, and streamlining assessment. However, these opportunities come with complex challenges that require a critical and responsible approach. Data privacy, algorithmic bias, equity of access, decisional transparency, and redefining the role of the teacher are just some of the issues that need to be thoroughly explored to ensure the ethical and effective integration of AI in education.

Overall, AI cannot replace the human dimension of education, but it can significantly enhance teachers' ability to create relevant and effective learning experiences. The future of English language teaching depends on how technology is integrated into a pedagogical framework that values human interaction, linguistic diversity, and educational equity. A critical, reflective, and balanced approach is essential to transform AI into a tool that supports, not replaces, the educational process.

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OPEN-END INVESTMENT FUNDS – THE KEY TO SMART DIVER

Lect. Alina SOLOVASTRU Ph.D.; Prof. Polotca OVIDIU Ph.D.

“Dimitrie Cantemir” University of Targu Mureș, Romania, Faculty of Economic Sciences, Romania
Corresponding author - Alina Nicoleta Solovastru: alina.solovastru@yahoo.com

Abstract

Open-end investment funds occupy a central place in contemporary portfolio construction by offering a practical, regulated and cost-efficient pathway to diversification for retail and institutional investors alike. This paper examines the mechanisms, benefits and limitations of open-end funds and explains why they represent a cornerstone of smart diversification strategies. Through pooled investment, these vehicles enable exposure to a broad universe of assets—equities, bonds, mixed and money market instruments—reducing idiosyncratic risk and allowing investors to achieve risk profiles that would otherwise require substantial capital and expertise. The presence of professional fund management, scale economies and access to research improves security selection and portfolio rebalancing, while transparent pricing and redemption features preserve liquidity for investors. We analyze the trade-offs between active and passive open-end funds, illustrating how fee structures, tracking error and manager skill impact net returns and diversification efficiency. Regulatory safeguards and disclosure requirements further protect investors, although they also impose constraints on leverage and illiquid asset holdings, which can affect performance in stressed markets. Using a synthesis of recent empirical studies and comparative examples, the paper highlights practical considerations for incorporating open-end funds into multi-asset portfolios, including correlations across asset classes, expense layering, tax implications and rebalancing rules. The discussion emphasizes investor-centric design: matching fund choice to investment horizon, risk tolerance and liquidity needs. Finally, we present recommendations for financial advisors and individual investors seeking to optimize diversification via open-end funds—prioritize low-cost exposure to broad asset classes, complement core passive exposures with targeted active strategies where skill is evident, and maintain disciplined rebalancing to capture diversification benefits. Open-end funds are not a universal panacea, but when selected and implemented thoughtfully they remain a powerful, accessible tool for achieving diversified portfolios and improved risk-adjusted outcomes. Ongoing investor education and careful due diligence are essential to realize their full long-term potential consistently.

Keywords: open-end funds; diversification; portfolio construction; liquidity; cost-efficiency

1. Introduction

The financial landscape of the 21st century is defined by a paradox of accessibility and complexity. Technological advancements have democratized access to capital markets, allowing individuals to trade securities from handheld devices with unprecedented ease. However, the underlying dynamics of the global economy have become increasingly opaque

and volatile. Factors such as geopolitical fragmentation, fluctuating inflation rates, divergence in central bank monetary policies, and rapid technological disruption create a non-linear market environment where traditional, concentrated investment strategies often fail. In this context, the defensive investor faces a critical challenge: how to participate in global economic growth while protecting capital from catastrophic loss.

Benjamin Graham, the father of value investing, famously posited that the intelligent investor must place their primary emphasis on the avoidance of serious losses rather than the pursuit of superior gains [1]. This philosophy elevates the importance of diversification from a mere recommendation to a fundamental necessity. However, a distinction must be made between "naive diversification"—simply holding a random assortment of stocks—and "smart diversification." Smart diversification is a disciplined, mathematical approach that accounts for correlation, covariance, and standard deviation to minimize portfolio volatility.

For most individual investors, achieving this level of sophistication independently is prohibitively expensive and logistically difficult. This brings the **Open-End Investment Fund** into focus. Often referred to as mutual funds, these vehicles pool capital from thousands of investors to purchase a broad portfolio of securities managed by professional entities. This paper posits that open - end investment funds are not merely financial products but are the "key" to unlocking smart diversification. By outsourcing complex decisions of asset allocation to professional managers, investors can bypass the limitations of individual capital constraints and gain exposure to global growth engines.

The paper is structured to first provide a theoretical understanding of open-end funds and their regulatory mechanisms under the UCITS directive. It then transitions into the theory of diversification, explaining why a fund structure is mathematically superior to individual stock picking. Finally, the paper offers a concrete case study of the **OneMarkets** ecosystem in Romania. By analyzing the offers found on *onemarkets.ro*, we will demonstrate how the "Fund of Funds" structure and strategic partnerships with global asset managers provide a practical, turnkey solution for smart diversification in the local market.

2. The Mechanics and Regulation of Open-End Funds

To understand why open- end funds are the preferred vehicle for diversification, one must first understand their structural mechanics and the regulatory safety net that surrounds them. An open-end fund is a collective investment scheme that can issue redeem shares at any time. Unlike a closed-end fund, which has a fixed number of shares that trade on an exchange (often at a premium or discount to their actual value), an open- end fund creates new shares whenever an investor adds money and retires shares when an investor withdraws money.

2.1. Net Asset Value (NAV) and Liquidity

The critical feature of the open-end fund is the Net Asset Value (NAV). The NAV represents the per-share value of the fund's assets minus its liabilities. It is calculated at the end of each trading day based on the closing market prices of the portfolio's securities.

This mechanism ensures fairness and transparency. When an investor on a platform like *onemarkets.ro* decides to invest, they are purchasing units at the NAV calculated at the next valuation point. This direct link to the underlying assets is crucial for diversification because it guarantees that the investor's capital is immediately spread across the entire portfolio. If a fund holds 500 different bonds, an investment of just 100 RON effectively buys a fraction of all 500 bonds instantly. This immediate dispersion of capital is the first step in risk mitigation [2].

2.2. The Regulatory Safety Net: UCITS

In the European Union, and by extension in Romania, most open-end funds marketed to retail investors operate under the UCITS (Undertakings for Collective Investment in Transferable Securities) directive. This is a vital component of "smart diversification" because it enforces diversification by law.

Under UCITS rules, a fund generally cannot invest more than 5% of its assets in the securities of a single issuer (this limit can be raised to 10% in specific cases, provided that the total value of holdings over 5% does not exceed 40% of the fund's assets). This is known as the "5/10/40 rule." For an individual investor, replicating this level of mandatory risk spreading is difficult due to transaction costs. For an open- end fund, it is a regulatory requirement. This framework protects investors from catastrophic failure; even if one company in the fund's portfolio goes bankrupt, the impact on the total NAV is minimal due to the regulatory cap on exposure [3].

3. The Theory of Smart Diversification

Diversification is often summarized by the adage "don't put all your eggs in one basket." However, from an academic perspective, it relies on **Modern Portfolio Theory (MPT)**, pioneered by Harry Markowitz in 1952. MPT argues that an investment's risk and return should not be viewed alone but should be evaluated by how it affects the overall portfolio's risk and return.

3.1 Correlation and the Efficient Frontier

The "smart" aspect of diversification refers to correlation. Correlation is a statistical measure of how two securities move in relation to each other, ranging from -1 to +1.

- **Correlation of +1:** Assets move perfectly in sync (e.g., two oil companies).
- **Correlation of 0:** Assets move completely independently.
- **Correlation of -1:** Assets move in opposite directions.

The goal of a well-managed open- end fund is to combine assets with low or negative correlations. For example, high-quality government bonds often have a low correlation with equities. When stocks crash due to economic fear, investors often rush to the safety of bonds, driving bond prices up. Markowitz [4] demonstrated that by combining such assets, a portfolio can achieve the same expected return with significantly lower volatility. This allows the portfolio to sit on the "Efficient Frontier," the optimal balance of risk and reward.

Individual investors rarely have the data or software to calculate correlation matrices for their portfolios. Open-end fund managers, however, utilize sophisticated algorithmic tools to construct these optimal portfolios. This professional asset allocation is the defining difference between "owning many stocks" and "smart diversification."

3.2 Systematic vs. Unsystematic Risk

Smart diversification addresses two types of risk:

1. Unsystematic Risk (Specific Risk)

This is the risk tied to a specific company or industry (e.g., a CEO scandal, a strike, or a regulatory fine). This risk can be virtually eliminated through diversification. By holding a

basket of 50+ stocks via an open-end fund, the negative performance of one is offset by the positive performance of others.

2. Systematic Risk (Market Risk)

This is the risk inherent to the entire market (e.g., a recession, war, or interest rate hikes). While diversification cannot eliminate this entirely, "smart diversification" mitigates it by mixing asset classes (equities, bonds, cash, commodities) that react differently to macro-economic events [5].

4. Case Study: The One Markets Ecosystem (onemarkets.ro)

To bridge the gap between financial theory and practical application, it is essential to analyze how these diversification principles are executed in the Romanian market. A distinct example of modern open-end fund architecture is the **OneMarkets** initiative, distributed by **UniCredit Bank**. A review of the platform *onemarkets.ro* reveals a strategic approach that democratizes access to institutional-grade diversification for retail investors.

The One Markets model differs from traditional local mutual funds by operating on an "Open Architecture" and "Exclusive Partner" basis. Rather than relying solely on internal management, the platform creates investment solutions in collaboration with global asset management giants. This structure is the embodiment of smart diversification, operating on three distinct levels.

4.1 Level 1: Diversification of Expertise (The Multi-Manager Approach)

Standard open-end funds rely on a single management team's view of the market. If that team misreads the economic cycle, the entire fund suffers. One Markets mitigates this "manager risk" by partnering with distinct market leaders for specific strategies, such as:

- **BlackRock:** Known for its unparalleled risk management technology (Aladdin) and expertise in equities and ETFs.
- **PIMCO:** Globally recognized as a premier fixed-income (bond) manager.
- **Allianz Global Investors** and **J.P. Morgan Asset Management:** Leaders in active management and multi-asset strategies.

By selecting funds managed by these partners, a Romanian investor is not just diversifying assets, but diversifying *strategies*. For instance, a portfolio might hold a technology-focused component managed by BlackRock and a bond component managed by PIMCO. This ensures that the portfolio benefits from the "best-in-class" expertise for each specific asset class, a level of sophistication usually reserved for ultra-high-net-worth individuals [3].

4.2 Level 2: The "Fund of Funds" Structure

Many of the solutions detailed on *onemarkets.ro* utilize a "Fund of Funds" or a highly diversified feeder structure. In this model, the One Markets fund does not necessarily purchase individual stocks (like Apple or OMV Petrom) directly; instead, it purchases units in other investment funds.

From a diversification standpoint, this is exponentially powerful.

Example: If a One Markets strategy invests in 10 underlying funds, and each of those underlying funds holds 100 securities, the investor effectively holds an indirect position in 1,000 distinct securities.

Impact: This drastically reduces unsystematic risk. The failure of a single company within that web of 1,000 securities would have a negligible impact on the investor's total NAV. This structure allows the investor to capture the average return of the global economy while smoothing out the extreme volatility of single stocks [6].

4.3 Level 3: Strategic Asset Allocation (The Active Component)

The platform *onemarkets.ro* highlights funds tailored to specific risk profiles (e.g., Defensive, Balanced, Dynamic). "Smart diversification" is not static; it requires rebalancing. For example, in a **Balanced Profile** (often a mix of approx. 50% Equities and 50% Bonds), the correlation benefits are actively managed.

Scenario: If global stock markets rally significantly, the equity portion of the portfolio might grow to 60%, exposing the investor to higher risk. The active managers behind the One Markets solution will sell the overperforming equities and buy more bonds to bring the allocation back to 50 / 50. This disciplined process of "selling high and buying low" is automated within the fund, ensuring the investor maintains their target risk level without emotional interference.

5. Risk Management and the Investor Profile

While open- end funds provide the structural "key" to diversification, the investor must select the correct "door." Smart diversification is not a one-size-fits-all solution; it must be aligned with the investor's time horizon and risk tolerance.

5.1 The Role of Volatility and the Sharpe Ratio

Investors often make volatility mistakes for loss. In the context of open-end funds, volatility is the price paid for returns. As seen on *onemarkets.ro*, funds with higher potential returns (Dynamic profiles) exhibit higher volatility.

The One Markets funds aim to optimize this ratio. By including asset classes that act as shock absorbers (such as investment-grade bonds or money market instruments), the fund managers attempt to lower the denominator without proportionally sacrificing the numerator (returns) [7].

5.2 Behavioral Finance and Discipline

Daniel Kahneman [8], in *Thinking, Fast and Slow*, explains that investors are prone to cognitive biases, such as "loss aversion." Individual investors tend to panic and sell at the bottom of a market crash. Open-end funds act as a behavioral barrier. Because the fund is managed professionally and adheres to a strict prospectus, it does not panic. The "smart" component here is the removal of emotion from the investment process. By investing in a One Markets fund via a recurring savings plan, the investor benefits from "Dollar Cost Averaging," buying more units when prices are low and fewer when prices are high, automatically optimizing their entry point [9].

5.3 Currency and Inflation Risk

For Romanian investors, diversification has a crucial currency dimension. Holding all savings in RON deposits exposes wealth to local inflation and currency depreciation. Open-end funds offering exposure to Euro-denominated or USD-denominated assets (even if hedged back to RON) provide a critical hedge. The global nature of the partners listed on onemarkets.ro ensures that the underlying value of the investment is tied to hard currencies and strong economies (US, Germany, France), protecting the purchasing power of the local investor against domestic economic shocks [3].

5.4 The Cost of Diversification

It is important to acknowledge that the professional management provided by open-end funds comes with costs (management fees, entry/exit fees). Critics often argue for low-cost passive indexing. However, in volatile markets, the "smart" component of diversification—active risk management—adds value that can exceed the fee drag. The ability of a manager to rotate out of a failing sector or to increase cash positions during a crash is a service that passive indices do not provide. As Bogle [2] suggests, cost is a factor, but the net return after risk adjustment is the ultimate metric of success.

6. Conclusion

The complexity of the modern financial environment renders the traditional approach of "picking winners" obsolete for the average investor. As demonstrated through Modern Portfolio Theory, the most reliable path to wealth preservation and growth is not speculation, but diversification. Open-end investment funds stand as the primary vehicle for achieving this, offering liquidity, regulatory protection (UCITS), and professional execution.

The analysis of the **OneMarkets** platform serves as a testament to the evolution of this industry. By shifting from a local, single-manager model to a global, multi-partner ecosystem, One Markets provides a "turnkey" solution for smart diversification. Through structures like Fund of Funds and partnerships with entities like BlackRock and PIMCO, it allows Romanian investors to transcend the limitations of the local market. Ultimately, open-ended funds are the key to smart diversification because they transform the daunting task of analyzing thousands of global securities into a single, accessible, and professionally managed investment decision. For the intelligent investor, the goal is not to beat the market every day, but to remain in the market through a diversified vessel that withstands volatility over the long term [10].

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DIGITALIZATION AND ARTIFICIAL INTELLIGENCE IN THE ACCOUNTING PROFESSIONS

Lecturer Susana Irina IOSOF Ph.D.

“Dimitrie Cantemir” University of Târgu Mureș, Faculty of Economic Sciences, Romania
Corresponding author - Iosof Susana Irina: Isusana2004@yahoo.com

Abstract

Digitalization and artificial intelligence have a significant impact on accounting professions, transforming the way accountants and auditors carry out their activities. Improving efficiency and reducing errors. In the future, these accounting professions will be influenced by technological advancement and their integration of artificial intelligence, meaning that accountants and auditors will increasingly focus on accounting consulting and analysis. A series of technologies are integrated into financial accounting processes and consist of the automation of repetitive processes, advanced data analysis and access to real-time information. Digitalization and artificial intelligence in the accounting professions also bring a series of risks related to data security, the acquisition of new skills and a major impact on jobs. In conclusion, digitalization and artificial intelligence will profoundly transform the accounting professions and bring both opportunities and challenges and accountants and auditors will need to adapt by acquiring digital skills in order to manage their businesses

Keywords: digitization, processes, artificial intelligence, auditor, accountant, data, change

Introduction

In recent years, liberal professions such as that of the certified accountant and financial auditor have undergone and will continue to undergo a profound transformation generated by the acceleration of digitalization and the emergence of artificial intelligence, which radically changes the way accounting information is processed. The immediate consequence of these technological developments is a transformation of the competencies required of accounting professionals. They must possess not only solid knowledge of accounting, finance, taxation, and auditing, but also digital skills, including the ability to work with databases, interpret data, and analyze information generated by artificial intelligence. Artificial intelligence represents one of the most impactful innovations of recent decades for the accounting profession. While in the past accountants relied on manual processing and repetitive calculations, today many operations are automated, and the mission of the accountant in the economy is being redefined [1], [2].

From an ethical perspective, the accounting profession must find a balance between the use of technology and human responsibility. Although artificial intelligence can support decision-making processes, responsibility for data interpretation and the assumption of conclusions ultimately remains with the accountant.

The times have changed: whereas in the past the accountant was primarily associated with ledgers, manual calculations, and large volumes of printed documents, today the dominant

image is that of a professional working in intelligent accounting environments, using integrated information systems, databases, online platforms, and intelligent algorithms. This transformation represents not only a technical evolution but also a redefinition of the accountant's role in the economy and society, with artificial intelligence becoming a “colleague” of the accounting professional [5].

In my view, artificial intelligence adds a new dimension to this transformation. Through the use of machine learning algorithms, very large volumes of data can be analyzed, patterns can be identified, and predictions can be made regarding a company's financial performance. Once trained, artificial intelligence can also detect unusual transactions, signal fraud risks or fiscal non-compliance, and support accounting and auditing activities. Queries addressed to virtual assistants can provide answers to frequently asked questions, generate preliminary explanations, and assist accountants in documentation and report drafting. As a result, the accounting profession is changing: the accountant is no longer focused on data processing but is becoming an analyst and strategic advisor, capable of transforming accounting information into business decisions.

Accounting professionals will increasingly rely on modern accounting software, ERP solutions, and cloud-based applications that enable automatic transaction recording, data integration from multiple sources, and the rapid generation of financial reports. Activities that previously consumed a significant amount of accountants' time — such as invoice entry, bank reconciliation, and document archiving — are now largely automated. This shift has led to increased efficiency, reduced errors, and real-time access to information relevant for managerial decision-making [4].

We should not fear that the accounting profession will disappear; rather, artificial intelligence will transform and enrich it, making it certainly much more attractive. Moreover, accountants will no longer be burdened by routine work, which will allow them to better capitalize on their analytical and communication skills. The future of the accounting profession will be shaped by collaboration between humans and technology, where success will depend not only on the performance of digital systems, but also on the accountant's ability to use them with discernment, responsibility, and vision.

At the same time, digitalization and artificial intelligence also bring a series of risks. Challenges related to the protection of personal data and the confidentiality of financial information become extremely important, as any security breaches may have significant consequences. On the other hand, the risk of excessive dependence on technology may lead to algorithm-generated errors remaining undiscovered due to insufficient understanding of these algorithms and inadequate monitoring. In addition, the rapid pace of change creates a need for continuous professional training, which may place pressure on specialists in the accounting professions. In the future, this profession will, in my view, become more attractive to young people and new generations, who will act as agents of responsible change. Therefore, educational institutions with an economic profile will have a central mission to teach young people how to interpret data, integrate sustainable development into their projections, and apply accounting reasoning in financial and accounting analyses. The fundamental principles of the accounting profession — such as professional integrity, independence, and responsibility — remain essential, even as more technological tools are used.

Next, we will analyze how digitalization and artificial intelligence will transform the accounting profession, reshaping both daily work practices and the strategic role of the accountant within the firm.

First, the digital revolution will automate repetitive tasks, meaning that a range of operations — such as invoice entry, bank reconciliation, document classification, and archiving — will be

performed by computer systems. The automatic input of data will not only reduce processing time but will also eliminate certain human errors. In the traditional accounting framework, accountants spent a considerable amount of time identifying errors arising from manual data entry. With this significant digital transformation, the role of the accountant will change: rather than focusing on routine operations, accountants will be required to analyze and interpret data and to advise the firm on financial and accounting matters. Their role will increasingly involve integrating information through multidisciplinary knowledge that combines accounting, taxation, and sustainable development.

All this digitalization will change the way work is organized within organizations, which will operate differently as artificial intelligence — through specialized software and robotic systems — takes over activities that were previously performed on a routine basis. This transformation will lead to a new organizational model in which the primary role is held by employees, particularly accounting professionals, and by their professional accounting judgment.

Operations will become much faster, resulting in time savings and increased efficiency and labor productivity. Under these conditions, costs will decrease, although this may also involve the displacement of employees who are unable to adapt to technological change, as technology can operate continuously, 24 hours a day, without fatigue or loss of concentration, allowing the overall volume of organizational activity to increase.

Another important aspect concerns the reduction of human errors as a result of the elimination of repetitive tasks that previously generated mistakes due to loss of concentration and the high volume of operations, which often led to lower-quality outcomes in the context of multiple activities. By transferring these routine tasks to digital systems and artificial intelligence, operational accuracy and the quality of results will increase, and control processes will be carried out much more efficiently.

In this context, accounting professionals will need to reinvent themselves and move beyond the role of bureaucrats performing standard operations, which will largely be taken over by computers. Instead, they will be required to develop analytical and decision-making capabilities. Their work will become more creative, but it will also require strong skills in communication, consultancy, innovation, and coordination. Only those professionals who understand the need to combine professional judgment with critical thinking and creativity will succeed in this evolving environment.

The takeover of certain activities by intelligent machines will lead to the disappearance of some professions (such as cashiers), the loss of certain jobs, and the need for professional reconversion, as well as the acquisition of new knowledge in the field of information technology to develop new competencies for a continuously evolving labor market. In such a highly technologized society, university and postgraduate education, as well as lifelong learning programs, will become essential. Perhaps more than ever, people will need to recognize that technology cannot replace them; however, in order to meet new challenges, they must engage in continuous learning, thereby reducing fears related to job loss.

The automation of repetitive tasks is an irreversible process that cannot be resisted, just as the introduction of computers once took over operations that had previously been performed manually. What is far more important is to redefine our role within a digital ecosystem and to focus more on creativity, critical thinking, communication, and strategy, as all these changes bring speed and productivity but also involve social, educational, and ethical responsibility. In my view, there will be no competition between humans and machines; rather, there will be collaboration, in which technology takes over repetitive tasks while humans concentrate on other aspects, such as applying professional judgment to generate real added value.

One of the opportunities brought by the digital revolution lies in real-time data analysis and, implicitly, in the assessment of the financial performance of organizations. It is well known that the information sector has expanded significantly in the digital era, and companies generate large volumes of data that require analysis, interpretation, and transformation into useful tools for the accounting profession.

Digital data analysis involves the use of information technologies, algorithms, and statistical methods to collect, process, visualize, and interpret information — an approach that is carried out much faster and more accurately than traditional methods. In this context, such information also serves as a foundation for decision-making, particularly in the marketplace. In today's business environment, data analysis enables sales forecasting, evaluation of customer behavior, cost optimization, and the identification of market opportunities. In the public sector, advanced data analysis can support policy formulation, efficient resource allocation, and the monitoring of social services.

Advanced financial data analysis relies on algorithms capable of identifying patterns, trends, and anomalies in large volumes of information far more quickly than humans could achieve. Through predictive models, artificial intelligence can support cash flow estimation, risk assessment, anticipation of financial performance, and the detection of early warning signs of insolvency. This capability transforms accounting from a discipline focused solely on recording the past into a forward-looking, future-oriented instrument.

Artificial intelligence, including virtual assistant applications, can provide preliminary explanations for clients, assist in the development of internal procedures, synthesize legislative changes, and offer examples of reports or explanatory notes. However, even though these tools are provided by artificial intelligence, professional responsibility and the final decision remain with the accountant, who must verify and interpret the automatically generated materials.

The development of artificial intelligence and machine learning has provided an additional impetus to this field. Algorithms can analyze enormous volumes of information, identify regularities, and generate predictions with a high degree of accuracy. Applications range from financial diagnostics to the detection of financial fraud. Digital analysis is no longer limited to describing the past; instead, it becomes a forward-looking tool through predictive models and simulations. Nevertheless, it is important to remember that all this advanced data processing has no meaning without human involvement. People play a key role in this economic mechanism, and their presence in the digital landscape depends on their competencies, their partnership with technology, and their interdisciplinary skills. Algorithms cannot assess data quality, understand economic context, or interpret the financial results and performance of an organization.

The challenges faced by accounting professionals stem primarily from the principle of data confidentiality, as improper use of data may lead to violations of fundamental rights. In addition, data quality is essential for sound decision-making, since incomplete or erroneous data can result in inadequate decision support [6]. Excessive reliance on technology and the assumption that it always provides accurate information may also lead to a lack of verification and, consequently, to incorrect decisions.

The labor market will likewise face numerous challenges, including the disappearance of certain professions, the transformation of others, and the emergence of new roles. The ability to adapt to the current technological environment — characterized by automation and artificial intelligence — will be a key asset in a continuously evolving labor market [2]; [3].

The transformation of digital skills driven by rapid technological change also leads to significant shifts in professional competencies, meaning that it is no longer sufficient to simply accumulate knowledge. Instead, greater emphasis is placed on the interconnectivity of

information, adaptability, flexibility, and lifelong learning. Collaboration, connectivity, and work practices themselves are evolving in an era in which digital competencies are essential, and working with computers, specialized applications, and online data platforms has become imperative. In addition to digital skills, transversal competencies — such as teamwork, rapid problem-solving ability, creativity, and originality — will make the difference. It is widely acknowledged that digitalization and artificial intelligence are reshaping economic activities and processes, from analysis to communication and project management. Continuous learning will be the key to success, with training courses and certifications having a significant impact on career development. In an era of constantly changing information, adaptation and lifelong learning will be decisive factors.

A balance between technology and real social life must be maintained, as excessive reliance on technology may lead to problems affecting mental health, resulting in isolation, anxiety, and reduced capacity for concentration.

The risks that arise in the digital era are closely related to cybersecurity and include identity theft, cyberattacks, data theft and unauthorized access to databases, as well as online fraud. These are processes we encounter increasingly often, and vulnerable institutions will need to invest in data protection in order to avoid creating institutional-level vulnerabilities. Nevertheless, the risks of the digital era do not negate its benefits, but they require a conscious and responsible approach. Technology is a powerful tool, and the way it is used depends on the education, values, and rules that society develops. The digital future can be a secure one if we succeed in combining innovation with ethics, security with freedom, and efficiency with the protection of human dignity.

Conclusion

In conclusion, the accounting profession is undergoing major changes, operating in a fully digitalized environment in which the transformation of professional competencies represents not merely an adjustment of knowledge, but a profound shift in how work itself is understood and performed. Technology, digitalization, and artificial intelligence do not diminish the role of humans; rather, they challenge them to evolve. The future belongs to professionals who are capable of continuous learning, rapid adaptation, and the integration of technical and human skills in a balanced manner that serves both economic progress and personal and social development.

Throughout this paper, it has been shown that artificial intelligence can be highly beneficial in accounting activities, not only in drafting procedures and accounting policies, but also in preparing financial statements, reports, and legislative syntheses. In any context involving the use of artificial intelligence, however, responsibility for verification remains with the human professional, and in this case, the final decision rests with the accounting professional.

The future accountant will be increasingly interconnected within a digitalized environment, adopting approaches from diverse fields such as management, tax consultancy, and strategy, and will play a crucial role in ensuring data quality control, thereby redefining the nature of their work.

In conclusion, digitalization and artificial intelligence do not replace the accounting profession; rather, they redefine it. These technologies take over repetitive tasks and increase efficiency, while the accountant evolves toward the role of analyst and strategic advisor. The introduction of artificial intelligence into accounting will also drive a transformation of professional competencies. As a result, accountants will need to possess multidisciplinary

knowledge in accounting and taxation, information technology, data analysis, and sustainable development economics.

In conclusion, the role of artificial intelligence in accounting is complex and continuously expanding. Artificial intelligence brings efficiency, speed, and advanced analytical capabilities, transforming the way daily accounting activities are carried out. At the same time, it raises professional standards and shifts the focus from processing to interpretation and advisory functions. The future of accounting will be shaped by collaboration between humans and technology, and success will depend on the ability of accounting professionals to use artificial intelligence with competence and responsibility. Success will belong to those who combine technical skills with human capabilities, engage in continuous learning, and understand that the true mission of the accountant is to provide trust, clarity, and guidance in the complexity of modern economic life.

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THE USE OF ARTIFICIAL INTELLIGENCE IN INDUSTRY 4.0 FOR PRODUCT QUALITY ASSURANCE

Lecturer Margareta CIOTEA Ph.D.¹; Alexandra CIOTEA²

¹*“Dimitrie Cantemir” University of Târgu Mureș, Faculty of Economic Sciences, Romania;*

²*Hirshmann Automotive of Târgu Mureș*

Corresponding author - Ciotea Margareta: cioteam@yahoo.com

Abstract

Industry 4.0 represents the current stage of industrial transformation, characterized by digitalization, connectivity, and the integration of advanced technologies such as the Internet of Things (IoT), big data, intelligent robotics, and artificial intelligence (AI). Quality assurance is an essential element for the success of any organization that produces goods or services. In the current context of digitalization and the increasing complexity of industrial processes, companies seek fast and efficient solutions to maintain continuous control over product quality. Artificial intelligence (AI) has become a crucial tool in the modernization and automation of inspection processes, enabling early defect detection, cost reduction, and increased productivity.

Keywords: artificial intelligence; Industry 4.0; quality assurance; smart manufacturing; automated inspection

Introduction

1. Industry 4.0 Context

Industry 4.0 represents a new stage in the evolution of production systems, characterized by digitalization, advanced automation, and the intelligent interconnection of equipment, processes, and information systems. This industrial paradigm integrates technologies such as the Internet of Things (IoT), cyber-physical systems, big data analytics, and artificial intelligence (AI), with the aim of increasing flexibility, efficiency, and competitiveness within industrial organizations.

In this context, ensuring product quality becomes an essential element for maintaining performance standards and meeting the increasingly stringent demands of the market. Traditional quality control methods, largely based on manual inspections or sampling techniques, are often insufficient to cope with the complexity and accelerated pace of modern production processes. These limitations necessitate the adoption of intelligent solutions capable of monitoring and controlling quality in real time.

Artificial intelligence plays a central role in transforming quality assurance processes within the framework of Industry 4.0. Through the use of machine learning algorithms, computer vision techniques, and predictive systems, AI enables the rapid identification of defects, the anticipation of non-conformities, and the continuous optimization of production processes. As a result, decisions are no longer based exclusively on human experience, but on the intelligent analysis of data collected from across the entire production system.

The aim of this article is to analyze how artificial intelligence contributes to product quality assurance in the context of Industry 4.0, highlighting the main applications, benefits, and challenges associated with the implementation of this technology. The article seeks to provide an overall perspective on the impact of AI on quality management and to emphasize the importance of adopting intelligent solutions for the sustainable development of modern industry.

Importance of Product Quality Assurance in the Modern Industrial Environment

In the modern industrial environment, characterized by global competition, high customer expectations, and increasingly shorter product life cycles, quality assurance represents a strategic factor essential to organizational success. Product quality is no longer perceived solely as a technical requirement, but as a decisive element influencing company reputation, customer satisfaction, and long-term competitiveness.

Through the continuous analysis of data generated during the manufacturing process, AI-based systems can identify critical points, sources of variation, and parameters that directly influence product quality. Based on these insights, automatic or assisted process adjustments can be implemented to maintain optimal operating conditions. AI-driven optimization enables improved quality consistency, reduced variability, and increased operational efficiency.

Moreover, this approach supports continuous process improvement and facilitates rapid adaptation to changing production requirements, thereby strengthening the competitiveness of industrial organizations in the current environment. At the same time, it contributes to defect reduction, minimization of scrap, and limitation of rework or product returns. Early identification of non-conformities in the production process allows for timely and effective interventions, preventing significant losses of material resources, time, and energy. In addition, well-controlled processes lead to optimal equipment utilization and increased overall productivity.

In the current context, where international quality standards and legal regulations are becoming increasingly stringent, companies must demonstrate product compliance with technical specifications and safety requirements. Effective quality assurance systems facilitate adherence to these standards and ensure product traceability throughout the entire production chain, which is essential in industries such as automotive, aerospace, and food processing.

Moreover, consistent product quality directly influences customer satisfaction and loyalty. Reliable and compliant products increase consumer trust and strengthen a company's market position. In a dynamic industrial environment, the ability to deliver high-quality products in a short time frame becomes a major competitive advantage.

Therefore, quality assurance in the modern industrial environment is no longer an isolated activity, but an integrated process supported by advanced technologies and oriented toward continuous improvement. The implementation of intelligent quality control solutions is essential for adapting to the requirements of Industry 4.0 and for maintaining long-term competitiveness.

The Role of Artificial Intelligence (AI) in Transforming Production Processes

Artificial intelligence plays a fundamental role in transforming production processes within Industry 4.0, contributing to the transition from traditional, rigid systems to intelligent, adaptive, and autonomous systems. Through its ability to analyze large volumes of data, learn

from experience, and make real-time decisions, AI redefines the way production activities are planned, monitored, and optimized.

One of the main ways in which AI influences production processes is through intelligent automation. Unlike traditional automation, which is based on fixed rules, AI-based solutions can adapt operating parameters according to the real conditions of the process. Machine learning algorithms enable the continuous adjustment of processes in order to maximize efficiency, reduce variability, and maintain a consistent level of product quality.

AI also facilitates real-time monitoring of production processes through integration with sensors, IoT systems, and data analytics platforms. The collected information is analyzed to identify patterns, trends, or anomalies that may indicate imminent failures or deviations from optimal parameters. This enables the implementation of predictive maintenance, reducing downtime and the costs associated with unplanned stoppages.

Another essential aspect of production process transformation is AI's ability to support decision-making. Intelligent systems can provide recommendations based on historical and real-time data, helping operators and managers make informed decisions regarding production planning, resource allocation, or the optimization of technological workflows. In this way, the flexibility and responsiveness of production systems to changes in demand or operating conditions are significantly improved.

By integrating artificial intelligence into production processes, companies can achieve higher levels of efficiency, quality, and sustainability. AI not only optimizes existing processes but also opens new perspectives for the development of intelligent production systems capable of self-improvement and dynamic responses to the challenges of the modern industrial environment.

2. Industry 4.0 and Quality Management

Definition of the Industry 4.0 Concept

Industry 4.0 represents the fourth industrial revolution and refers to the profound transformation of production systems through the integration of advanced digital technologies into industrial processes. The concept was first introduced in Germany and describes the transition from traditional factories to smart factories, where equipment, systems, and products are interconnected and communicate with each other in real time.

At the core of Industry 4.0 lies the use of cyber-physical systems, which combine the physical components of production processes with information systems capable of monitoring, controlling, and autonomously optimizing these processes. These systems are supported by technologies such as the Internet of Things (IoT), artificial intelligence, big data analytics, cloud computing, and advanced robotics.

A defining element of Industry 4.0 is the ability to collect and analyze data in real time across the entire production chain, from supply to the delivery of the final product. This approach enables improved traceability, high process flexibility, and product customization according to specific customer requirements, without compromising efficiency or quality.

Industry 4.0 is not limited to process automation but also focuses on the creation of intelligent production systems capable of adapting to change, preventing errors, and continuously optimizing performance. Consequently, this concept represents a new industrial model oriented toward efficiency, innovation, and competitiveness, with a significant impact on how products are designed, manufactured, and controlled in the modern industrial environment.

Evolution of Quality Management Systems

Quality management systems have evolved significantly over time in response to industrial development, increasing process complexity, and the growing demands of the market. Initially, quality was approached in a reactive manner and was mainly associated with final product inspection. The purpose of this stage was to identify defects after the product had been completed, without systematic control of the processes that generated these defects.

With the advancement of manufacturing practices, quality control began to be integrated into the production process itself. Statistical methods, such as Statistical Process Control (SPC), were introduced, enabling the monitoring of process variations and the identification of the root causes of defects. This stage represented an important step toward error prevention and improved process stability.

In the current context, quality management systems have further evolved through the integration of artificial intelligence. By continuously analyzing data generated during the manufacturing process, AI-based systems can identify critical points, sources of variation, and parameters that directly influence product quality. Based on these insights, automatic or assisted process adjustments can be implemented to maintain optimal operating conditions. AI-driven optimization improves quality consistency, reduces variability, and increases operational efficiency.

Subsequently, the concept of quality assurance expanded the perspective on quality by encompassing all stages of the product life cycle, from design and procurement to production and delivery. Quality became a shared responsibility across the entire organization, supported by documented procedures, internal audits, and international standards such as the ISO 9000 series. During this stage, defect prevention and customer satisfaction became central objectives.

In the context of the global economy and intense competition, quality management systems evolved toward approaches focused on continuous improvement and operational excellence. Methodologies such as Total Quality Management (TQM), Six Sigma, and Lean Manufacturing emphasized variation reduction, waste elimination, and the active involvement of employees in improvement processes.

At present, with the emergence of Industry 4.0, quality management systems have entered a new phase of digital transformation. The integration of technologies such as artificial intelligence, IoT, and advanced data analytics enables the transition from reactive or preventive systems to predictive and adaptive ones. As a result, quality management becomes more efficient, more transparent, and increasingly oriented toward data-driven decision-making, effectively responding to the demands of the modern industrial environment.

Current Challenges in Product Quality Assurance

Product quality assurance in today's industrial environment faces numerous challenges driven by the increasing complexity of production processes, the diversification of customer requirements, and the rapid pace of technological innovation. Companies are required to maintain high quality standards while operating under conditions of large production volumes and constant pressure on costs and delivery times.

One of the main challenges is the growing complexity of products and technological processes. Modern products integrate multiple components and technologies, making it difficult to identify and control all the factors that can influence quality. In this context, traditional control methods based on manual inspections or sampling become insufficient and may lead to the late detection of defects.

Another major challenge is the management of the large volumes of data generated during production processes. Although data can provide valuable insights for quality improvement, the lack of advanced analytical and interpretation tools limits organizations' ability to use this information effectively. Without intelligent analysis, data remain underutilized or are only partially incorporated into the decision-making process.

Process and raw material variability also represent a significant source of non-conformities. Fluctuations in production parameters, environmental conditions, or supplier quality can affect the consistency of final products. Controlling these variations requires flexible and adaptive systems capable of responding rapidly to change.

In addition, companies face increasing pressure to comply with international standards and legal regulations, as well as the need to ensure full product traceability. Implementing and maintaining compliant quality systems involves high costs and requires qualified personnel, which can be a barrier, particularly for small and medium-sized enterprises.

Finally, the shortage of specialized skills in quality management and digital technologies constitutes a significant challenge. Adapting to the new requirements of Industry 4.0 requires continuous employee training and a shift in organizational culture—key factors for the successful implementation of modern quality assurance systems.

The Need for Digitalization and Automation of Quality Control Processes

In the context of Industry 4.0, the digitalization and automation of quality control processes have become essential in order to respond to the increasingly complex demands of the modern industrial environment. The growth in production volumes, product diversification, and rising customer expectations require efficient, fast, and reliable solutions for quality monitoring and assurance.

Traditional quality control processes, largely based on human intervention, are often limited by subjectivity, errors, and long execution times. Manual inspections may be inefficient in high-speed production lines and do not allow for the detection of all defects, particularly subtle or sporadic ones. Digitalization enables the automatic and continuous collection of data from production processes, providing a comprehensive, real-time overview of quality status.

The automation of quality control processes, through the use of intelligent sensors, computer vision systems, and advanced analytical algorithms, contributes to increased inspection accuracy and consistency. These solutions enable the rapid identification of non-conformities, reduced response times, and the implementation of corrective measures before defects propagate throughout the production process.

Another major advantage of digitalization is the possibility of advanced data analysis and the use of predictive models. By integrating artificial intelligence technologies, quality control systems can anticipate the occurrence of defects, identify the root causes of variations, and automatically optimize process parameters. As a result, quality control evolves from a reactive approach to a predictive and preventive one.

Furthermore, digitalization and automation facilitate product traceability and compliance with international quality standards. Data are stored and managed in a structured manner, enabling more efficient audits and greater transparency across the entire production chain. Therefore, the adoption of digital and automated solutions in quality control is no longer an option, but a necessity for companies seeking to maintain competitiveness and ensure a high and consistent level of product quality.

3. Applications of Artificial Intelligence in Product Quality Assurance

Automatic Product Inspection Using Computer Vision via the Keyence IV3 AI Camera Tool

Automatic product inspection through computer vision represents one of the most effective applications of artificial intelligence in quality assurance within the framework of Industry 4.0. Modern vision systems enable fast and accurate verification of product characteristics, eliminating the limitations of manual inspections. A relevant example in this regard is the Keyence IV3 smart camera, which integrates advanced artificial intelligence tools for quality control.

The Keyence IV3 camera uses AI-based image recognition algorithms to identify defects, dimensional deviations, or assembly errors, even under conditions of variation in lighting, product position, or appearance. Unlike traditional vision systems, which require complex settings and detailed programming, the AI tools of the IV3 enable the system to “learn” product characteristics based on reference images. As a result, the system can distinguish between compliant and non-compliant products with a high degree of accuracy.



Figure 1. Automatic inspection of products using computer vision (source: <https://www.keyence.com.br/products/vision/vision-sensor/iv3/>)

This figure illustrates an example of **AI-based automatic product inspection** using a computer vision system — specifically, the Keyence IV3 smart vision camera. The image demonstrates how the system captures visual data from products on a production line and applies advanced AI algorithms to detect defects, dimensional deviations, and assembly errors. By leveraging artificial intelligence and machine learning, the system is able to “learn” product features from reference images and distinguish compliant products from non-conforming ones with high accuracy, even under varying lighting or positioning conditions, thus enhancing quality control within Industry 4.0 environments.

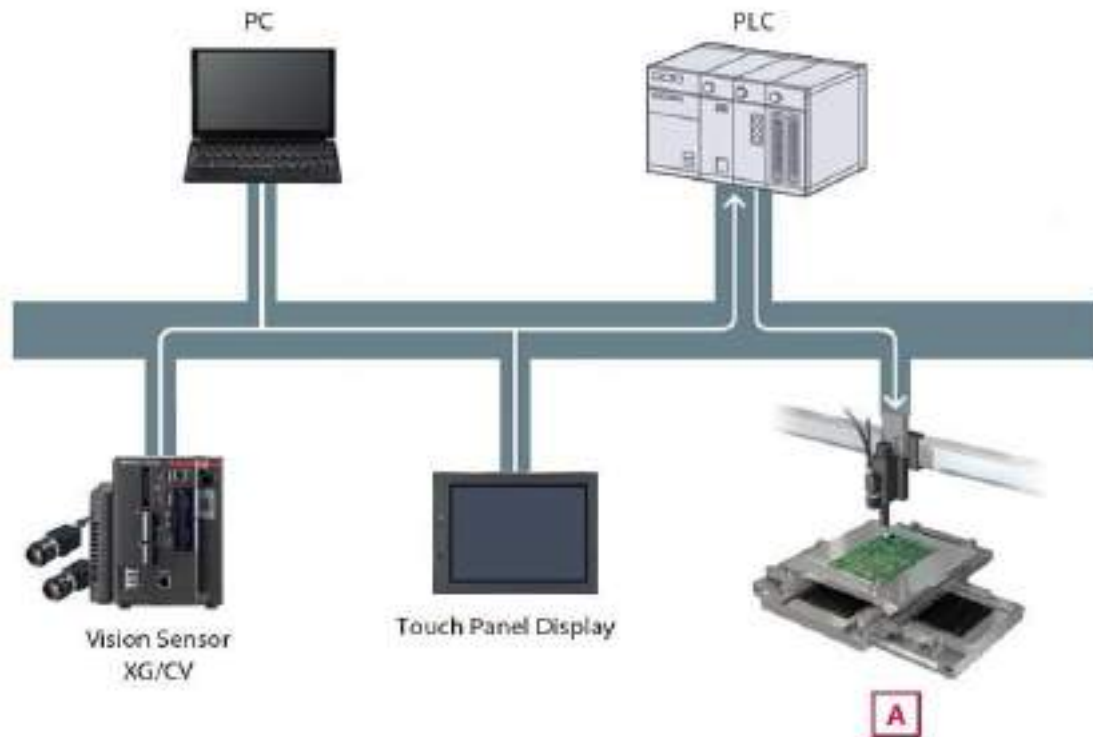


Figure 2. Example of connection in an industrial control system using PLC and HMI (source: <https://www.keyence.com.br/products/vision/vision-sensor/iv3/>)

This figure illustrates the typical architecture of an industrial automation system in which a vision sensor is integrated with a PLC (Programmable Logic Controller) and an HMI (Human–Machine Interface). The vision sensor (XG/CV) captures and processes images of the product on the production line and sends inspection results to the PLC. Based on this information, the PLC controls the industrial process (e.g., accept/reject decisions or actuator commands). A PC is used for configuration and monitoring, while the touch panel display (HMI) allows operators to visualize inspection results and system status in real time. This integration enables automated, reliable, and real-time quality control in Industry 4.0 environments.

The connection within an industrial control system using a PLC (Programmable Logic Controller) and an HMI (Human–Machine Interface) shows how a vision sensor can communicate with a PLC and a control panel in order to transmit inspection results and automate decisions on the production line.

The IV3 series is a vision sensor with integrated AI developed by Keyence for industrial visual inspection applications. It combines the camera, lens, and lighting into a single device, while artificial intelligence automates image capture settings and detection processes. The system can differentiate between compliant (“OK”) and non-compliant (“NG”) products (Fig. 1).

The AI automatically optimizes the image for detection. It adjusts lighting, exposure, and capture mode so that the final image is clear and stable, without reflections or dark areas.

A major advantage of using the Keyence IV3 camera is its ability to perform real-time inspections directly on the production line. The system can verify the presence or absence of components, correct assembly, shape, color, or possible surface defects. Inspection results are provided instantly, allowing the process to be stopped or non-compliant products to be automatically rejected, which contributes to reducing scrap and associated costs.

In addition, the integrated AI tools facilitate rapid adaptation to changes in products or processes. When a new type of product is introduced, the system can be reconfigured simply by updating the set of training images, without requiring complex parameter adjustments. This flexibility is essential in modern production environments characterized by customization and small production batches.

By integrating the Keyence IV3 camera into quality control systems, companies can benefit from an automated, reliable, and scalable inspection process. The use of artificial vision based on artificial intelligence contributes to increased consistency in product quality, reduced dependence on the human factor, and improved overall performance of production processes.

Real-time Detection of Defects and Anomalies

Real-time detection of defects and anomalies is an essential aspect of quality assurance within Industry 4.0. By using artificial intelligence and advanced monitoring systems, it becomes possible to immediately identify deviations from the normal parameters of the production process. Machine learning algorithms analyze data collected from sensors, artificial vision systems, and industrial equipment, identifying unusual patterns that may indicate the occurrence of defects.

This approach enables rapid intervention before non-conforming products reach the final stages of production or the customer. Moreover, real-time detection reduces the risk of defect accumulation, minimizes material losses, and contributes to maintaining a consistent level of quality. AI-based systems are capable of continuous operation with high accuracy, eliminating the limitations of manual inspections and the subjectivity of the human factor.

Predicția Defectelor și a Neconformităților

The prediction of defects and nonconformities represents a natural evolution of quality control, made possible by predictive analytics based on artificial intelligence. By using historical data together with information collected in real time, machine learning models can anticipate the occurrence of defects before they actually manifest in the final product.

These models identify complex relationships between process parameters, environmental conditions, equipment status, and product quality. As a result, preventive alerts can be generated, allowing production parameters to be adjusted or maintenance activities to be scheduled before nonconformities occur. Defect prediction contributes to reducing unplanned downtime, lowering costs, and increasing the reliability of production processes.

Optimization of Production Processes for Quality Improvement

The optimization of production processes represents an essential element in improving product quality, especially in the context of Industry 4.0, where industrial processes are increasingly complex and interconnected. Artificial intelligence plays a key role in this optimization through its ability to analyze large volumes of data in real time and to identify relationships between process parameters and the quality of final products.

By using machine learning algorithms, intelligent systems can identify the root causes of quality variations and determine the optimal operating parameters of equipment. This analysis enables the continuous adjustment of production processes in order to maintain a consistent level of quality, even under changing conditions related to raw materials, production requirements, or environmental factors.

An important advantage of AI-based optimization is the possibility of automating decision-making. Systems can recommend or automatically apply changes to process settings to prevent the occurrence of defects and reduce variability. As a result, process stability is improved and the risk of nonconformities is minimized, leading to reduced scrap and associated costs.

Furthermore, process optimization contributes to improved operational efficiency and resource utilization. Well-controlled processes consume less energy, materials, and time, having a positive impact on both product quality and production sustainability. In this context, artificial intelligence not only supports quality maintenance but also becomes a strategic tool for continuous improvement and for increasing the competitiveness of industrial organizations.

Conclusions

In the context of Industry 4.0, artificial intelligence represents a decisive factor in transforming production processes and ensuring a high level of product quality. The integration of advanced digital technologies — such as computer vision systems, real-time data analytics, and machine learning algorithms — enables the transition from traditional quality control methods to intelligent, predictive, and adaptive systems.

The use of artificial intelligence in quality assurance significantly contributes to the rapid detection of defects, the anticipation of nonconformities, and the continuous optimization of production processes. These capabilities lead to reduced scrap, lower operational costs, and increased overall efficiency of industrial systems. At the same time, consistent product quality enhances customer satisfaction and strengthens organizations' competitive positioning in the market.

Although the implementation of AI-based solutions involves challenges — such as the need for initial investments, the management of large data volumes, and the development of specialized skills — the long-term benefits justify the adoption of these technologies. The digitalization and automation of quality control processes are no longer optional but have become a necessity for companies seeking to adapt to current industrial requirements.

In conclusion, artificial intelligence has a major impact on product quality assurance within Industry 4.0, providing the foundation for the development of intelligent, efficient, and sustainable production systems. The widespread adoption of these solutions will contribute to the evolution of quality management and to the creation of an industrial environment oriented toward innovation and continuous improvement.

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Epilogue – Beyond Intelligence: The University as a Space of Responsibility in the Algorithmic Era

This volume has traversed a broad and complex intellectual landscape situated at the intersection of technology, education, law, social sciences, health, and economics. This diversity is not incidental; rather, it reflects the very nature of artificial intelligence as a transversal phenomenon that can no longer be understood or governed through the lens of a single discipline. In this sense, the contributions assembled here do more than examine the impact of AI on specific fields — they outline a conceptual map of how academic knowledge itself is being reshaped in a world increasingly governed by data, algorithms, and autonomous systems.

The contemporary university stands at a historical point of inflection. Whereas in previous centuries its primary role was the preservation and transmission of knowledge, today its mission extends toward the critical shaping of the future. Artificial intelligence is not merely a tool of technological progress; it is a force that reconfigures the relationships between human agency and knowledge, between decision-making and responsibility, between autonomy and automation. Within this context, higher education emerges as a space for ethical reflection and intellectual governance, where not only digital skills are cultivated, but also professional consciences capable of understanding the broader social consequences of innovation.

The texts included in this volume demonstrate that the true challenge of artificial intelligence is not purely technological, but profoundly human. Whether addressing the protection of fundamental rights, mental health, social equity, economic sustainability, or the education of future professionals, the central concern remains the same: maintaining a balanced relationship between algorithmic efficiency and moral judgment, between automation and empathy, between innovation and responsibility.

From this perspective, the university cannot function merely as a testing ground for emerging technologies. It must remain a forum for critical debate and interdisciplinary dialogue. Its role is to build bridges between the exact sciences and the humanities, between technical expertise and social wisdom, between economic progress and the common good. Viewed in this light, artificial intelligence becomes not only an object of study, but a catalyst for a new academic culture — one grounded in responsibility, transparency, and civic engagement.

Looking ahead, this volume does not offer definitive answers but rather opens a space for essential questions. What kinds of professionals do we seek to educate in a world of algorithm-assisted decision-making? How can we safeguard the autonomy of thought in environments increasingly shaped by predictive systems? And, above all, how can the university continue to serve as a bastion of humanistic values in an age of artificial intelligence?

The answers to these questions will not emerge from a single discipline, institution, or academic culture. They will be constructed through collaboration, dialogue, and sustained reflection — precisely the spirit that animates the pages of this volume. In this sense, the present work does not mark an endpoint, but rather a point of departure for a global academic community committed to the responsible exploration of the future of education, knowledge, and digital society.

Associate Professor Sorina-Mihaela BĂLAN Ph.D.



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