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EDITORS

Carmen Elena CÎRNU • Ella Magdalena CIUPERCĂ

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Section 1

Changing Education Because of Technology Disruption

Using Artificial Intelligence in universities

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Abstract: *The purpose of this paper was to present the impact of Artificial Intelligence (AI) on education. AI helps education in at least two ways: the educational process – assistance and modifications to pedagogy and educator's routine function; and the educational ambit and content – what kind of education is needed. In this article, the author explores the challenges and potentialities that AI offers in education. This paper, which has an extensive literature review, is conducted to reveal how Higher Education Institutions (HEIs) have benefited from AI and must be met to prepare for such powerful technology.*

Keywords: Intelligent Education, Artificial Intelligence Integration, Educational Innovation, Higher education institutions.

1. Introduction

This paper highlights the progress made by “Gh. Asachi” Technical University and the Iași University Centre regarding the introduction and development of Artificial Intelligence Aided Education (AIED) in the fields of Science, Technology, Engineering, Arts, and Mathematics (STEAM). General Association of Engineers of Romania (AGIR) and Technical Sciences Academy of Romania (ASTR) have permanently supported the efforts of "Gh. Asachi" Technical University from Iasi to update Engineering Education in Romania (Zhang et al., 2024).

The paper addresses implementing educational strategies based on artificial intelligence and promotes a more effective educational environment. The paper is organized as follows: Section 2 focuses on Universities Empowered with Artificial Intelligence. Section 3 provides the Requirements of HEIs to Meet the AI Revolution. Section 4 presents the conclusion and future work.

2. Universities empowered with Artificial Intelligence

AI applications in higher education sectors are classified into three main kinds of applications: institutional, student support, and instructional (Chen, Chen, & Lin, 2020; Alam, 2021; Khatun et al., 2024; Burlacu, 2024; Borisova, Hadzhikoleva, & Hadzhikolev, 2023; Oprea, 2021; Oprea, 2024). These three

broad categories can be broken down into several applications as displayed in Figure 1. The AI systems will play a major role in bringing about effectiveness in the making of institutional decisions via systems in marketing, admission and enrolment, curricula, and resource planning.

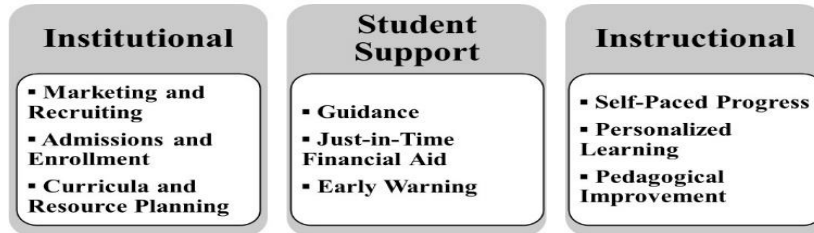


Figure 1. AI applications in higher education (broad categories), (Al-Haimi et al., 2021)

The AI applications that are being used in universities and Higher Education Institutions (HEIs) are based on the student's lifecycle approach, which is classified into two sections: (1) institutional and administration level and (2) academic support system.

Table 1. The AI functions in educational scenarios.
(Chen, Chen & Lin, 2020; European Commission, 2022)

	The work AI can do in Education
Administration	<ul style="list-style-type: none"> ▪ Perform the administrative tasks faster that consume much of instructors' time, such as grading exams, and providing feedback ▪ Identify the learning styles and preferences of each of their students, helping them build personalized learning plans. ▪ Assist instructors in decision support and data-driven work. ▪ Give feedback and work with students timely and direct.
Instruction	<ul style="list-style-type: none"> ▪ Anticipate how well a student exceeds expectations in projects and exercises and the odds of dropping out the school. ▪ Analyse the syllabus and course material to propose customized content. ▪ Allow instruction beyond the classroom and into the higher-level education, supporting collaboration. ▪ Tailor teaching methods for each student based on their personal data. ▪ Help instructors create personalized learning plans for each Student.
Learning	<ul style="list-style-type: none"> ▪ Uncover the learning shortcomings of Student and address them early in education ▪ Customize the University course selection for Students. ▪ Predict the career path for each Student by gathering studying data. ▪ Detect learning state and apply intelligent adaptive intervention to students.

AI systems will greatly assist students through financial aid and early warnings to avoid any risks. Moreover, these systems will increase the effectiveness of teaching and learning through various intelligence systems. The functions of AI in Education are summarized in Table 1.

As presented in Figure 2, various AI applications being used are categorized into four major areas. These identified areas are profiling and prediction, assessment and evaluation, adaptive system and personalization, and intelligent tutoring system (Metzler & Martincic, 1998; Shute, 1995).

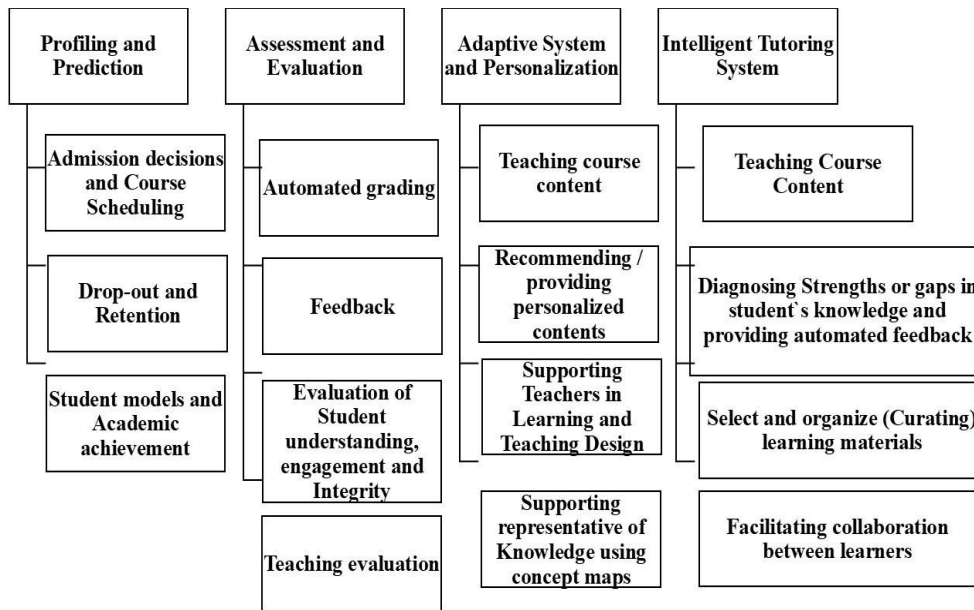


Figure 2. AI applications used in HEIs, (Papasyridis, 2020; Al-Haimi et al., 2021)

All the mentioned systems and applications enabled by AI technology have led to students' success. Student success in a university or college is a crucial criterion for examining and measuring the success and quality of the educational institution.

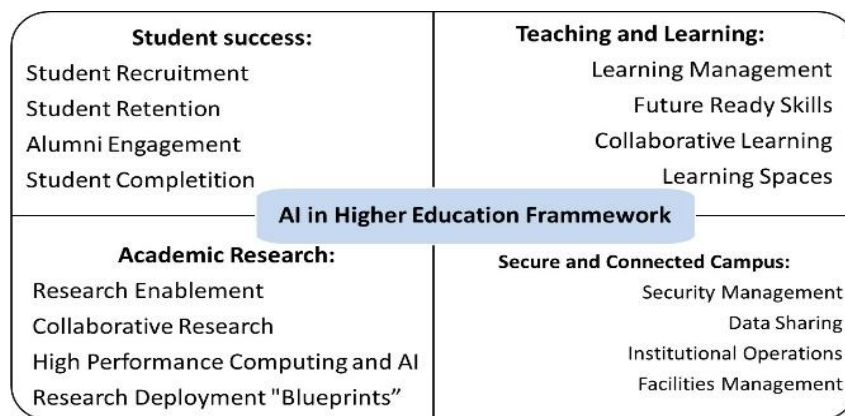


Figure 3. Framework of AI in higher education. Source ((Papasyridis, 2020)

Consequently, implementing such applications and systems will lead to the success and better performance of any existing higher education. A broader framework of AI in higher education has been presented by the Microsoft Education Transformation Framework (ETF) in higher education, cited in (Papaspnyridis, 2020). Based on this framework, higher education (Figure 3) benefits from AI through four major areas: 1) student success, 2) teaching and learning, 3) academic research, and 4) secure and connected campus. These areas are discussed below.

2.1 Student success

Student success is the cornerstone and the core function of any existing university. HEIs are expected to produce a high-quality and skilful workforce. Over time, technologies keep changing and thus universities and colleges are coping with the changes to prepare their students to meet the marketplace needs. For this reason, the emerging powerful technology of AI will benefit the HEIs.

For instance, because of the disruptive nature of AI classroom technology, it possesses a significant ability to modify or alter the teaching styles and the manner of presenting educational resources in the process of preparing students to achieve their career goals. Faculty members will have to be faced with new experiences and opportunities which they need to brace up to. Consequently, this situation will enable faculty members to identify and properly instil AI in the syllabus and the style of teaching, thereby bringing higher education into new instructional styles. To ensure student success, many applications of students' admissions, retentions, engagement, and tracking performance are being used in some HEIs.

In the field of teaching and learning (Dennis, 2018; Fattoh, 2014), AI is widely involved in applications that affect the methods of teaching and learning in universities. In fact, higher education has already taken the first step towards an unknown zone of the opportunities opened by AI in teaching and learning as well as institutions and governance. AI has created a new environment for teaching and learning, thus leading to further collaborations among students.

Global classrooms and massive open online courses (MOOCs) are examples of successful applications that turned the higher education environment into a new normal. MOOCs courses that are useful and interesting have been in use since 2008. Other applications, such as intelligent tutoring systems, have numerous benefits for teaching and learning. These benefits can be reflected in the teaching of course content, diagnosis of strengths or gaps in students' knowledge, automated feedback, curating of learning materials, and facilitation of collaboration between learners.

For example, the University of Georgia uses AI in administrative processes and in monitoring and tracking individual student's performance, predicting marks and dropouts or course withdrawals. Along with other universities, it also uses AI chatbot technology and other applications to simplify students' lives. Chatbot

technology, such as chatterbots, talkbots, virtual assistants, or conversation systems, are AI applications that use natural language to interact with users, such as university students, to facilitate teaching processes and to help the librarian. This kind of technology is widely used in Poland universities.

An AI application responds to questions from freshmen. Another AI application, a monitoring system, utilizes student data to predict student's performance and the possibility of dropping out. Thus, AI is promising and will benefit HEIs in terms of streamlining students' success, given that students nowadays are engaged with technology.

2.2 Teaching and learning

In the future, AI applications will be used beyond our expectations because they will reshape the perspective on the skill sets that students must gain to prepare them for the workplace. Several insights into how AI has helped higher education in teaching and learning: (1) AI helps lecturers analyse and recognize students' comprehension of topics through their facial expressions; it also assists in evaluating homework (e.g., activities in Coursera). (2) AI provides constructive feedback for students and lecturers. (3) AI will be used as a substitute for the teaching-and-learning process in which lecturers act as facilitators.

During the pandemic ages of COVID-19, the majority of HEIs worldwide have completely moved to online teaching and learning; however, handling online exams remains an obstacle. Many universities have started using AI application services and systems, such as remote Proctorio, Examity, Honorlock, and ProctorU, to monitor and record students during their online exams. Another example of AI application being used for teaching and learning in higher education is called teacherbot and IBM's Watson (Teaching Assistant) which afford an automated teacher presence throughout the course duration. The development of AI Technology will reshape the teaching and learning process of higher education.

2.3 Academic research

The number of publications worldwide reveals a considerable expansion of knowledge and data access. In 2018, a total of 2.6 million publications on science and engineering were issued; this number is a great indicator of how academic research is rapidly expanding. With such vast knowledge and data, AI plays a vital role in empowering researchers to analyse, share, visualize, and disseminate data in an effective manner through various tools.

Currently, AI technology facilitates the work of academic researchers by enabling search engines to perform quick and real-time searches. In addition, AI applications contribute to research and academic integrity. HEIs use detection systems to check plagiarism whereas publishers use AI to automate systematic academic literature reviews to detect ethical research behaviour before publication.

Furthermore, AI can write an essay instead of human writing; thus, AI will also be able to distinguish between human- and AI-written essays.

Secure and Connected Campus. The fourth dimension of the AI framework in higher education is a secure and connected campus. With the revolution of technologies and its effect on students' lives, innovative ways of learning are required. The world is shifting to "smart" buildings, cities, campuses, universities, and homes, which all require substantial IT infrastructure.

Nowadays, a successful model of smart and connected campuses is Birmingham City University, where a strong technological infrastructure costs £180 M. As a result, physical infrastructure, data and research sharing, operations, and facility management within the universities and campuses will have a secure and safe environment, that is conducive to students' learning experiences.

3. Requirements of HEIs to meet AI revolution

The benefits and promises of AI reveal how AI transforms businesses and the workforce and skills required by the marketplace and industries (Al-Haimi et al., 2021). Figure 4 shows the different ways in which the action plan has adapted higher education institutions in China to the new opportunities and benefits that AI can produce.

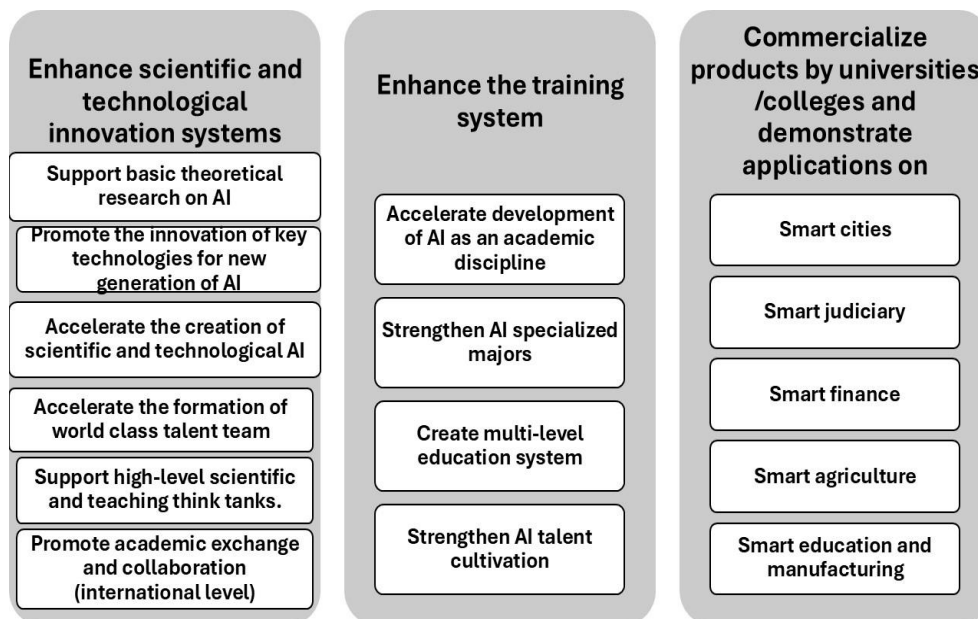


Figure 4. Key tasks in China's AI action plan for HEIs (Al-Haimi et al., 2021)

AI technology will drastically reshape the workforce, thus making higher education institutions prepare students to deal with such changes. Higher education institutions (Papaspolidis, 2020) need to plan, design, prepare, and

develop strategies on how to deal with the upcoming wave of the 4IR (Fourth Industrial Revolution) in general and the AI revolution in particular.

Governments, industries and sectors, including higher education institutions, have initiated several initiatives and allocated budgets for such projects. In line with these initiatives, the researchers published several articles on how higher education institutions should prepare for 4IR in general and the AI revolution in particular. China's AI Innovation Action Plan for Higher Education Institutions has launched several initiatives and requirements to prepare higher education institutions for their role in AI development.

AI Readiness		
<p>Strategy:</p> <ul style="list-style-type: none"> • Ambition, • Alignment, • Approach 	<p>People:</p> <p>Organizational Design, Talent Model, Change and Communication</p>	<p>Technology and Platforms:</p> <ul style="list-style-type: none"> • Deployment Models, • Security and Continuity, • Architecture and Tools
<p>Process:</p> <ul style="list-style-type: none"> • Measurement and Funding, • Delivery, • Governance 	<p>Ethics:</p> <ul style="list-style-type: none"> • Transparency and Explainability, • Policies • Bias and Integrity 	<p>Data:</p> <ul style="list-style-type: none"> • Enterprise Data Strategy, • Data Discipline • Security, Privacy and Compliance

Figure 5. Six dimensions for assessing AI readiness (AI-Haimi et al., 2021)

The strategy focuses on human capital as it aims to produce AI-related skills at different levels of education by creating networks, establishing a regulatory and ethical framework, and creating a data infrastructure for AI.

Each country needs to establish a strategy for the use of AI in education, including Higher Education. Figure 5 presents a comprehensive framework that assesses the readiness of any government organization for AI. This framework encompasses six important dimensions: strategy, people, processes, ethics, data and technology, and platforms. An interesting example of a framework for implementing AI in universities is the AI Center at the University of Malaysia Kelantan.

The major components of this framework are presented in Figure 6. These components are classified into two levels: The Ministry of Higher Education level and the University level. At the Ministry of Higher Education level, AI policies, standards, AI centres, and AI leadership are among the main components. At the university level, AI applications, AI infrastructure, and infostructure are needed to ensure the implementation of AI technology in the country. Developing strategies for AI implementation is an important element, as AI is a transformative technology that requires considerable effort and budget.

The second dimension for assessing the AI readiness of any organization is managing the problem of people in the organization. Problems in this dimension can be presented in the form of accessing, and attracting the necessary qualified

and talented people, training existing employees, and changing management in the organization.

The third dimension is assessing the implementation of AI. The assessment of this main dimension is done by measuring policies, allocating resources that increase the number of graduates and enrolments, and delivering through increased advocacy and promotion, as outlined in the AI Action Plan. The assessment can also be done through a strong and clear governance system to ensure the successful implementation of AI.

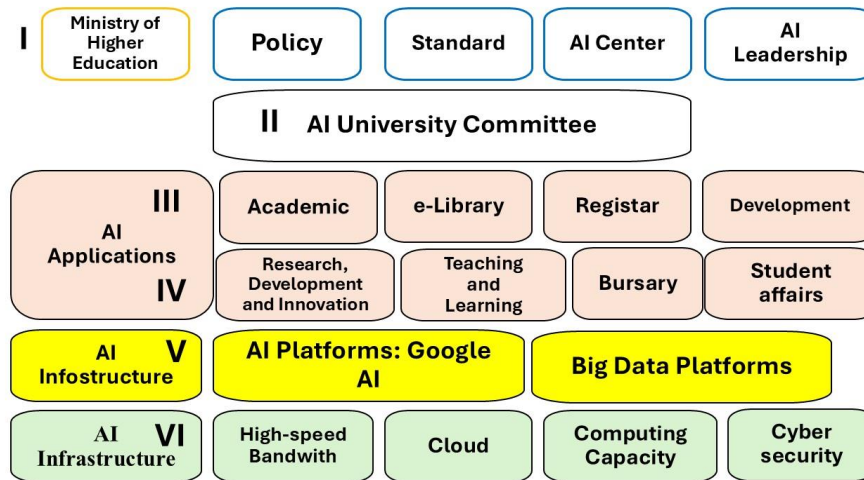


Figure 6. AI implementation in the University. (Al-Haimi et al., 2021)

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4. Conclusions

The objective of the article was to present, analyse and evaluate the impact of AI on education. Articles from journals, professional publications, and professional conference reports were identified and used in an analysis that

facilitated the achievement of the study's objective. AI technologies can contribute to a more personalized, efficient and inclusive education system. This information and conclusions are relevant for academic institutions and policymakers seeking to adapt education systems to the demands of the digital age. AI will mainly help students with learning difficulties and evaluate performance with constructive feedback.

Teachers will use artificial intelligence technology to help students (chatbots to recognize and solve questions asked by students during classroom lectures). Artificial intelligence will help improve the quality of distance and online education (Ng, Leung, Su, et al., 2023; Railean et al., 2023). AI is used in learning technology systems that include virtual reality (VR), and augmented reality (AR).

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Generative AI in Education: A bibliometric analysis

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Abstract: *In this study, a search was conducted in the Web of Science database on the topic of “Generative AI in Education”. This search was tabulated with bibliometric analysis and the data was presented. The bibliometric analysis was performed using VosViewer software. The aim of this study is to determine which authors, sources and countries have done the most work by performing a bibliometric analysis of “Generative AI in Education”. On February 6, 2025, topics were selected in the Web of Science database and studies on “Generative AI in Education” were scanned. The countries with the most citations are the United States, Peoples r China and Spain. In addition, “Asia Pacific Journal of Education”, “Integrating Generative AI in Education to Achieve Sustainable” and “Interactive Learning Environments” are the most important studies related to “Generative AI in Education”. As a result, the majority of studies in this field are shaped around the concepts of artificial intelligence, chatgpt, education, generative AI, generative AI in education and higher education.*

Keywords: Artificial intelligence, Generative AI, Education, Artificial Intelligence in Education, Bibliometric Analysis, Generative AI in Education.

1. Introduction

Today, it examines the role of Generative AI in education and its connection to the UN Sustainable Development Goals (SDGs). The interdisciplinary, technical and ethical dimensions of AI in education are addressed by Doshi, Dadhich, Poddar, & Hiran (2024). Ching, Hsu & Hung (2024) stated in their study that AI in education has become widespread using OpenAI's ChatGPT and Google's Gemini, and that guides have been published by various institutes and organizations to increase AI literacy, but it is emphasized that the integration of Generative AI into education must be addressed robustly.

Okaiyeto, Bai & Xiao (2023) emphasized that as Generative AI has become widespread in education, concerns about AI and cheating, such as AI-assisted cheating, have emerged. In the US, some schools have imposed bans on the use of AI in homework and exams. OpenAI stated that ChatGPT has developed solutions to this issue and has suggested collaboration with educators. Adhikari, Kumbhakar, Indra & Karforma (2024). When the Impact of Generative AI in Education 2030 is examined in the book section, the foundations, evaluation, working process and

<https://doi.org/10.58503/icvl-v20y202502>

applications of Generative AI in 2030 education are examined. While examining the role of AI in innovation, education policy, research, teacher guidance in content production are highlighted.

Ng, Chan & Lo (2025) stated that the main challenges of integrating Generative AI into education, opportunities and strategies for its adoption, with data from 76 Canadian educators, are teachers' readiness levels, competencies and students' AI literacy. Lindell, & Utterberg (2025) examined the social impacts of 40 Swedish educators' challenges with generative AI by managing the Cultural-Historical Activity Theory.

Giannakos, Azevedo, Brusilovsky, Cukurova, Dimitriadis, Hernandez-Leo & Rienties (2024). Generative AI tools can be used for the development of practices such as automatic educational content, instructional design feedback, but ethical issues and potential for misuse are also emphasized. The research addresses the role of human experts, policy, support and design requirements. Considering Generative AI in education research in general, the aim of the research is to analyze current studies in this field with bibliometric analysis regarding citation of authors, co-occurrences of a keyword, bibliographic matching (coupling) of documents, bibliographic matching of sources and bibliographic matching of countries.

2. Method

In this study, a bibliometric analysis of the studies scanned in the Web of Science database under the title of "Generative AI in Education" was conducted. The aim of this study, which was conducted using the VosViewer software, was to determine which authors, which sources, and which countries conducted the most studies on the subject of "Generative AI in Education" through bibliometric analysis. On February 6, 2025, topics were selected in the Web of Science database and studies on the subject of "Generative AI in Education" were scanned. While performing the analyses, "Authors' citations, Synchronicity of all keywords, Bibliographic matching of documents, Bibliographic matching of sources, Bibliographic matching of countries" were examined. Within the scope of the research, the analyses of 47 studies on the subject of "Generative AI in Education" were tabulated and presented with graphics.

3. Findings

3.1 Citation of authors

When analyzing the data regarding citations of authors, the "minimum number of documents of an author" was identified as 1. The "minimum number of citations of an author 11 of the 164 authors, 9 meet the thresholds. Figure 1 and Table 1 show the most cited authors.

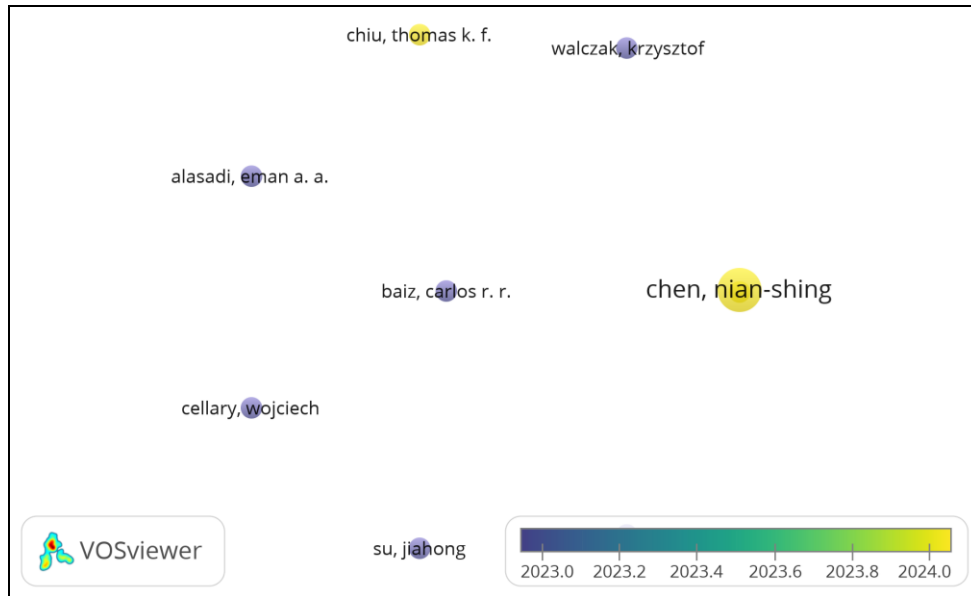


Figure 1. Graph generated with VosViewer for citation of authors

Table 1. Table of citations of authors

Author	Documents	Citations	Total link strength
"alasadi, eman a. a."	1	89	0
"baiz, carlos r. r."	1	89	0
"cellary, wojciech"	1	20	0
"chen, nian-shing"	2	17	1
"chiu, thomas k. f."	1	123	0
"lan, yu-ju"	1	16	1
"su, jiahong"	1	118	0
"walczak, krzysztof"	1	20	0
"yang, weipeng"	1	118	0

3.2 Co-occurrence-all keywords

While performing the relevant analysis, the “minimum number of occurrences of a keyword” was identified as 5. Among the 172 keywords, 7 meet the thresholds”. In Figure 2 and Table 2 highlights the ”Co-occurrence-all keywords”.

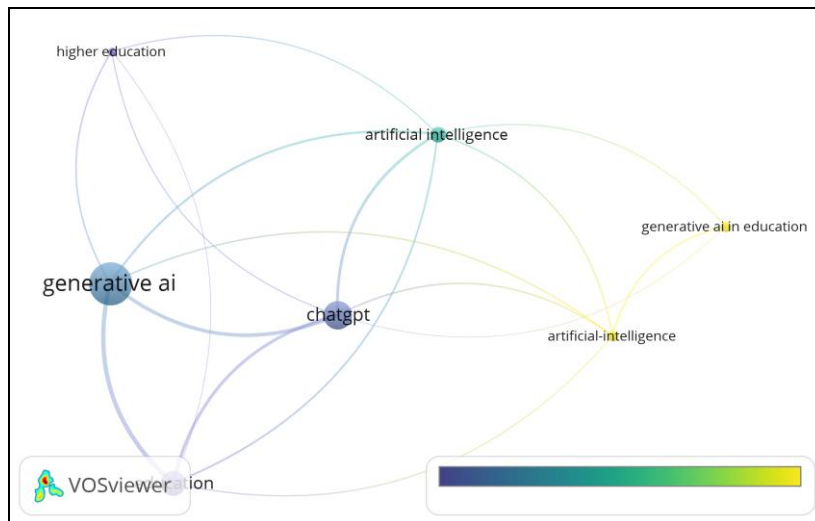


Figure 2. Graph generated with VosViewer for co-occurrence-all keywords

Table 2. Table for co-occurrence-all keywords

Keyword	Occurrences	Total link strength
artificial intelligence	9	23
artificial-intelligence	6	14
chatgpt	16	31
education	14	28
generative ai	24	34
generative ai in education	6	6
higher education	5	8

3.3 Bibliographic coupling of documents

While conducting the relevant analysis, the “minimum number of citations of a document” was selected as 5 of the 47 documents, 9 meet the threshold. In Figure 3 and Table 3 shows that “bibliographic coupling of documents”.

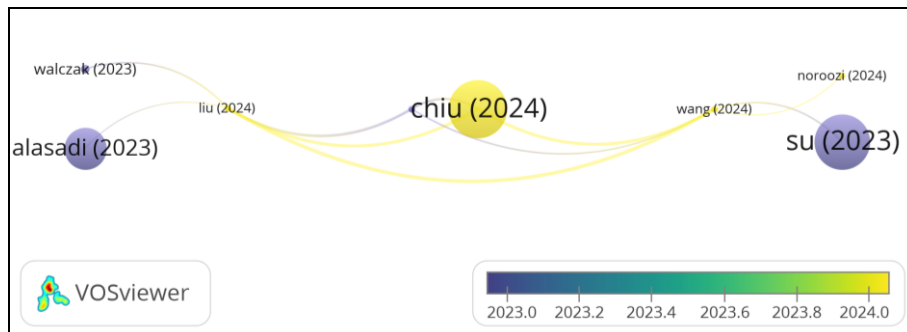


Figure 3. Graph generated with VosViewer for bibliographic coupling of documents

Table 3. Table for bibliographic coupling of documents

Document	Citations	Total link strength
liu (2024)	10	18
su (2023)	118	2
alasad (2023)	89	1
lan (2024)	16	0
walczak (2023)	20	2
chiu (2024)	123	13
wang (2024)	10	16
noroozi (2024)	8	1
bozkurt (2023)	9	9

3.4 Bibliographic coupling of sources

While conducting the relevant analysis, the “minimum number of documents of a source” was identified as 2. Minimum number of citations of a source” was selected as 0 of the 40 sources, 3 meet the thresholds. Figure 4 and Table 4 shows that bibliographic coupling of sources.

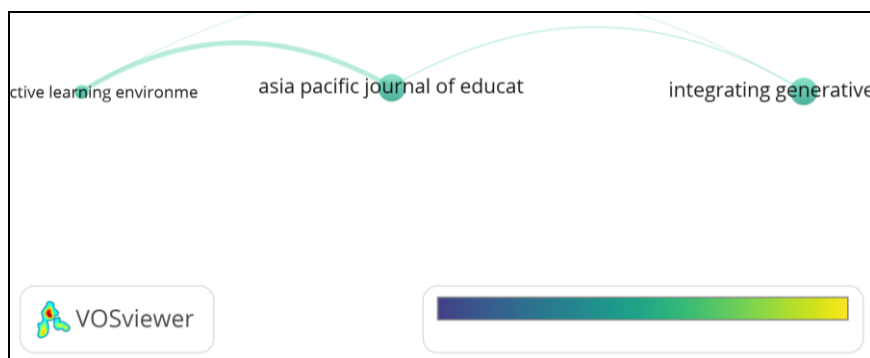


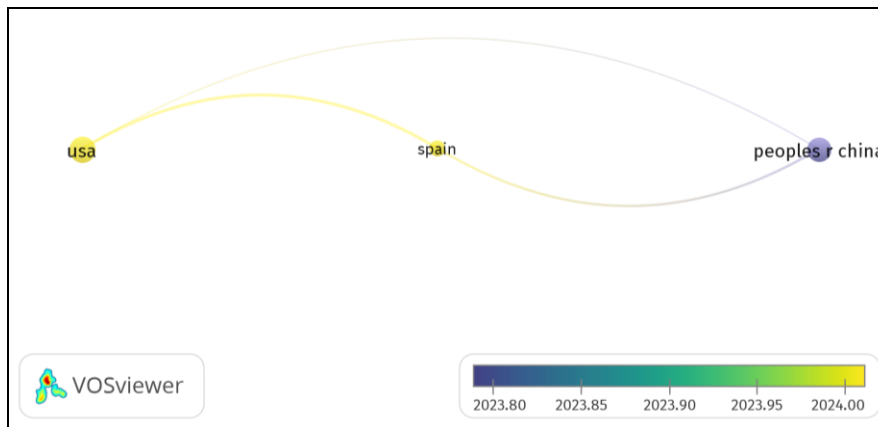
Figure 4. Graph generated with VosViewer for bibliographic coupling of sources

Table 4. Table for bibliographic coupling of sources

Source	Documents	Citations	Total link strength
asia pacific journal of education	4	25	20
integrating generative ai in education to achieve sustainable learning environments	4	0	6
interactive learning environments	2	123	18

3.5 Bibliographic coupling of countries

While conducting the relevant analysis, the “minimum number of documents of a country” was selected as 5. Minimum number of citations of a country 0 of the 35 countries, 3 meet the thresholds. Figure 5 and Table 5 shows the bibliographic coupling of countries.

**Figure 5.** Graph generated with VosViewer for bibliographic coupling of countries**Table 5.** Table for bibliographic coupling of countries

Country	Documents	Citations	Total link strength
Peoples Rep. China	9	270	145
Spain	6	9	267
USA	10	92	190

4. Discussion

The bibliometric analysis of the studies scanned with the keyword “Generative AI in Education” in the Web of Science database was presented with graphs and tables using VosViewer. When the findings were examined, it was seen that the most cited authors in this field were “Chiu, Thomas K. F.” (1 study, 123

citations), "su, jiahong" (1 study, 118 citations) and "yang, weipeng" (1 study, 118 citations).

According to the "Co-occurrence-all keywords" analysis, the most frequently used keywords in "Generative AI in Education" studies were generative ai, chatgpt, education, artificial intelligence, artificial-intelligence, generative ai in education, higher education, respectively.

Wen, Zhao & Zang (2025) emphasize the benefits of Generative AI such as personalization, content production, as well as concerns about addiction and academic ethical violations in information production. In their study on "higher education", one of the most used keywords, Francis, Jones & Smith (2025) highlight the need to address the disadvantages and digital divide risks in ethical issues while offering advantages with personalized learning and innovative assessment in higher education with generative AI. Nguyen (2025) expanded the article on the risks and academic honesty that may be experienced in the integration of generative AI in higher education, along with pedagogical and ethical principles. It is foreseen that the importance of human-artificial intelligence collaboration will be at the forefront, with ethical usage guidelines also taking an important place in the future by drawing attention to the importance of artificial intelligence literacy.

The most cited study according to the keyword "Generative AI in Education" is the study titled "The impact of Generative AI (GenAI) on practices, policies and research direction in education: a case of ChatGPT and Midjourney" by Chiu (2024). This study investigates the impact of Generative AI on school education from the perspective of teachers and administrators. The study presents 4 main themes and 12 sub-themes based on data collected from 88 participants. The study findings provide professional standards and implications for policy. The reason for the high citation of the study can be thought to be due to the fact that it suggests six future research directions for Generative AI in education.

It is seen that the most published sources are "Asia Pacific Journal of Education" and "integrating generative ai in education to achieve sustainable". In addition, the countries with the most publications are the USA, Peoples r China and Spain. These countries are among the countries where the most studies on Generative AI in Education have been conducted.

Su & Yang (2023) examined the advantages and difficulties of Generative AI tools such as ChatGPT in education. The advantages of Generative AI such as personalized learning and rapid feedback were emphasized. However, issues such as data quality, security and ethics were also addressed as disadvantages.

5. Conclusions and future studies

In this study, the studies scanned under the title "Generative AI in Education" in the Web of Science database were examined with the bibliometric

analysis method. VosViewer software was used to determine the most published authors, the most published sources, and the most researched countries.

When the findings were examined, Thomas K. F. CHIU from The Chinese University of Hong Kong, Jiahong Su from The University of Hong Kong, and Weipeng Yang from The Education University of Hong Kong are among the most influential academics in studies on Generative AI in Education. The countries with the most citations are the United States, Peoples r China, and Spain. In addition, the most important studies related to “Generative AI in Education” are “Asia Pacific Journal of Education”, “Integrating Generative AI in Education to Achieve Sustainable” and “Interactive Learning Environments”.

As a result, most of the studies in this field are shaped around the concepts of artificial intelligence, chatgpt, education, generative ai, generative ai in education and higher education. This research aims to guide future research in the relevant field by showing the current studies and the most cited studies on Generative AI in Education. In general, future studies on Generative AI should investigate its impact on the teaching-learning process, how the role of the teacher will transform, the development of artificial intelligence literacy, ethical risks, and how it can be integrated into educational policies.

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The hallucination problem in Generative Artificial Intelligence: accuracy and trust in digital learning

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Abstract: *Generative Artificial Intelligence (GenAI) changes digital learning systems by offering personalized content, adaptive feedback, and interactive study materials. This technology can help fill gaps in resources and reduce educational inequality. The main issue is that it also brings challenges. One major issue is called "The Hallucination Problem." This is when GenAI models create content that sounds believable but is actually false. If these errors are not detected in time, they can reduce trust in the technology and spread misinformation. This paper looks at how GenAI works and how it is transforming digital education. The reasons behind these hallucinations are examined, so mitigation risk strategies can be defined. In the end, using GenAI responsibly in digital education means that everyone, teachers, students, and institutions, must understand its risks and the need for systems which were built with human-in-the-loop methods. The best way of hallucination risks mitigation is hallucination awareness. This way, we can take advantage of new technology without sacrificing the quality of education.*

Keywords: artificial intelligence in e-learning, artificial intelligence hallucination, hallucination awareness.

1. Introduction

In an era defined by information, historian Yuval Noah Harari's observation that "having a lot of information doesn't in and of itself guarantee either truth or order" (Harari, 2024) emphasizes an interesting paradox related to modern education. Generative artificial intelligence is transforming the way we understand and develop e-learning systems, offering new opportunities for personalized learning, automated content creation, and adaptive learning systems. The integration of GenAI into educational frameworks introduces significant challenges. The most important risk associated with GenAI is AI "hallucinations", instances where models generate plausible content which is actually false. This paper emphasizes how generative AI reshapes digital education, analyses the implications of hallucinations, and proposes strategies to mitigate the risks associated with hallucination.

1.1 The evolving needs of new-age students

Nowadays students live in a digital connected world, where digital skills are essential. Unlike previous generations, they demand instant access to interactive content and expect learning platforms to adapt to their individual pace and preferences. The need for instant gratification transforms their responsiveness to traditional e-learning models, which are build on static and precise curricula.

Digital readiness and digital skills are critical factors influencing student engagement in e-learning environments. Research indicates that students who possess strong digital skills have confidence in their ability to navigate online learning platforms and tend to achieve better academic outcomes (Kim, Hong & Song, 2019). Furthermore, the Covid-19 pandemic has highlighted the urgent need for both educators and students to develop robust digital competencies, enabling them to respond effectively to modern educational challenges (Saienko, Kurysh & Siliutina, 2022). The ability to adapt to digital learning environments not only enhances student engagement but also helps to create a more equitable educational experience (Li, 2024).

Students face cognitive overload from fragmented information sources (most of information is delivered through mobile phone from different social media platforms), inconsistent feedback mechanisms, and limited opportunities for hands-on practice. For instance, STEM (science, technology, engineering, and mathematics) learners often lack access to lab equipment or real-world simulations, while language students require immersive conversational practice beyond textbook exercises (Sheily Panwar, 2024). These problems make it harder for students to develop the skills they need and increase inequality among them. This is especially true for those who have limited resources — such as not enough computers, reliable internet, or proper study materials. Without these essentials, it becomes even more difficult for them to keep up and gain the hands-on experience and feedback they need to succeed, but GenAI can offer scalable and personalized solutions at lower costs than before, which might mitigate the associated risks.

1.2 The Changing roles of educators in the digital age

As students increasingly rely on digital platforms and tools, educators face significant challenges in adapting to these new ways of learning. For many teachers, especially those who are new to digital literacy, acquiring digital skills can be more demanding. Older adults often acquire digital skills at a slower pace than younger individuals, primarily due to factors such as limited prior exposure to technology, age-related cognitive changes, and distinct learning preferences. Not only the learning methods and tools must adapt to new-age students, but also adapt to the teachers. Many older adults did not grow up with digital technologies, resulting in less familiarity and foundational knowledge, which can make learning new digital skills more challenging. In their study, (Pihlainen, Korjonen-Kuusipuro & Kärnä, 2021) highlights the role of educators in the digital age, emphasizing the importance

of adapting teaching methods to meet the unique needs of older learners. The conclusions of article points out the need for educators to develop digital skills and adopt flexible, learner-centered approaches to effectively facilitate digital literacy among older adults.

Cognitive changes associated with aging, such as reduced processing speed and memory retention, which leads to lack of confidence when using technology, can impact the learning process. Social and emotional barriers, like fear of making mistakes make the students feel intimidated, with a negative outcome their learning process. Instructors report that standard digital literacy programs are often ineffective, requiring more patient and personalized teaching methods, adapted to each individual (Vercruyssen et al., 2023).

The entire education system is being transformed by new technologies, reshaping teaching methods, student engagement, and access to learning resources. Also, the reduced attention span of students is another aspect worth considering. It is an ongoing struggle between the rapid emergence of new tools, teacher training, and timely adoption of these innovations to remain relevant. While technology offers opportunities for personalized learning and increased accessibility, its effectiveness depends on how well educators are prepared to integrate it into their teaching practices.

2. How generative AI works in e-learning?

Generative Artificial Intelligence represents a technology defined by the ability of machines to create new content, including text, images, audio, and video, by learning patterns from existing data. This technology uses complex algorithms, particularly deep learning models, which analyze different datasets to identify structures and patterns and generate outputs that is similar to human creativity. Generative AI have different forms, from Generative Adversarial Networks (GANs) used mostly for image generation, Variational Autoencoders (VAEs) used for data generation and dimensionality reduction, and transformer-based models like GPT (Generative Pre-trained Transformer), used for text generation based on user input named prompts (Ali et al., 2024). For instance, GANs consist of two neural networks, the generator and the discriminator, that work in the same time to produce realistic outputs, while transformer models utilize attention mechanisms to generate coherent and contextually relevant text (Sauvola et al., 2024).

Generative AI applications in e-learning are diverse and multiple, offering innovative solutions to improve educational experiences. One important example are the applications which are able to develop personalized learning environments. Generative AI can analyse individual learning patterns and preferences and create personalized content that meets the unique needs of each student (Rasul et al., 2023). For example, AI platforms can generate quizzes, exercises, and study materials that adapt in real-time based on a learner's progress, which promotes a more engaging and effective learning experience (Baidoo-Anu & Ansah, 2023). Also, Generative AI

can make the learning systems to adapt and adjust the difficulty of tasks based on the learner's performance, ensuring that students are consistently challenged without becoming overwhelmed (Chan, 2023). Another significant application of generative AI in e-learning is the instant feedback and support which can be offered during the learning phase. AI systems can evaluate student submissions and provide constructive feedback immediately, which is crucial for a better learning, encouraged by continuous improvement (Rasul et al., 2023). For instance, tools like ChatGPT can assist students in understanding complex concepts by generating explanations and examples based on their prompt. For example, the usage of different prompts (like 80-20 rule, known as Pareto principle), can help students to understand complex subjects. This capability not only enhances the learning process but also empowers educators by allowing them to focus on more complex pedagogical tasks while AI handles routine assessments and feedback (Baidoo-Anu & Ansah, 2023), (Rasul et al., 2023).

Generative AI (GenAI) refers to artificial intelligence that can create new content — text, images, music, or even code — by learning from vast amounts of data. Unlike traditional AI models that classify or predict based on predefined categories, GenAI generates original outputs based on patterns it has learned. A particular application of GenAI is the Large Language Models (LLMs) which are specifically designed to process and generate human-like text. They are built using deep learning techniques, particularly transformer architectures, and are trained on massive datasets containing books, articles, and Internet scrapped text. LLMs are evolving rapidly, with improvements in efficiency, reasoning capabilities, and multimodal understanding (combining text, images, and audio). As AI research progresses, we may see models that are more aligned with human reasoning and less dependent on massive datasets.

In Figure 1, the process of how Large Language Models (LLMs) generate text follows four key stages: **Input Processing**: the user provides a text prompt, which serves as the starting point for the model's response. This text is tokenized, meaning it is broken down into smaller units (words or characters) and converted into numerical representations that the model can process. Each token is mapped to an embedding, a dense vector representation that captures its meaning in relation to other words. **Model Processing** is the step where tokenized input is fed into a neural network, typically based on the transformer architecture. Inside the transformer, self-attention mechanisms allow the model to analyse the entire context rather than just relying on immediate neighboring words. The model uses its billions of pre-trained parameters to *determine the most probable next token*, adjusting based on context. The deeper the model, the more refined its understanding of complex structures, enabling nuanced and coherent responses.

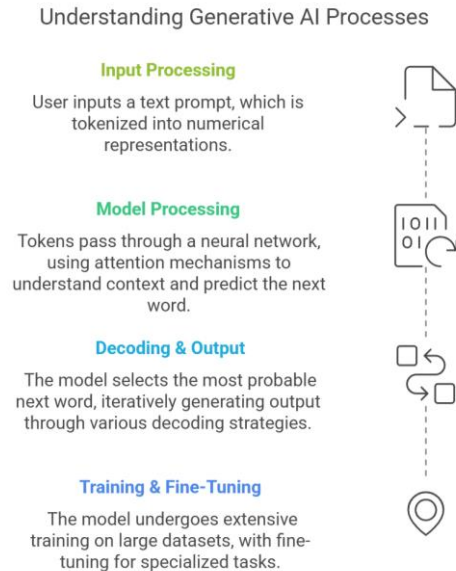


Figure 1. How Generative AI process works

Decoding & Output Generation: the model iteratively generates words based on probability distributions, selecting the next most likely token each time. Different decoding strategies influence output quality: Greedy search selects the most probable token at each step (fast but can lack diversity), Beam search considers multiple possible continuations before selecting the best one (improves coherence), Temperature control adjusts randomness — higher values make responses more creative, lower values make them deterministic. This cycle repeats until the model generates a complete and meaningful response. In the end, the last step in the for understanding how an LLM works is **Training & Fine-Tuning**, which is a background process. LLMs are pre-trained on vast datasets containing books, articles, and web text using self-supervised learning — predicting missing words in a sentence to learn patterns. Later, they undergo fine-tuning for specific applications, such as legal, medical, or conversational AI tasks, using curated datasets. Reinforcement Learning from Human Feedback (RLHF) can further refine model behaviour, making responses more aligned with user expectations.

3. The hallucination problem in GenAI

In the previous chapter, we learned that LLMs pick their next word based on which word is most likely to come next. However, this process can lead to a big issue: the model may provide information that sounds convincing but is actually wrong or made up. This problem is called “The Hallucination Problem”. The fact that LLMs can hallucinate is a significant concern in their development, particularly in the context of educational processes, where the accuracy is important.

3.1 The problem

The term "hallucination" in LLMs is used to describe outputs produced by different models (like Llama, BERT, Mistral) which do not correspond to any real-world facts or knowledge. A model can generate a statement about a historical event that never occurred or invent details about a scientific concept. This tendency is rooted in the way LLMs are trained and how they actually work; they learn to predict the next token in a sequence based on patterns in the training data, which can lead to the generation of fake information (Ji et al., 2023), (Maynez et al., 2020). Research has shown that hallucinations can manifest in various forms across different applications of LLMs. For example, in the domain of summarization, models often produce summaries that include fake facts or misunderstandings of the original content (Maynez et al., 2020). This is problematic in use-cases where users depend on these summaries for accurate information. Similarly, in question-answering tasks, LLMs may provide answers that are entirely made up, leading to a lack of trust in their outputs (Sadat et al., 2023).

To illustrate the impact of hallucination, consider a scenario in which university students conducting research on Romania's education system use an LLM to gather statistics about school enrolment rates in rural areas. The AI confidently provides outdated or entirely fabricated numbers, such as a "35% dropout rate in the Teleorman region," without citing real sources. Relying on these fictional figures can skew the conclusions of their research project, leading to flawed recommendations for policymakers or NGOs working to improve rural education.

Hallucination is mainly seen at inference time (when the model generates its outputs) but can be influenced by every stage of a model's life cycle, as described below:

- **Pre-Training Phase:** if the training data is incorrect or biased, the model may learn misleading correlations. Large, diverse datasets often include errors or unverified information, setting the stage for the model to generate incorrect answers later;
- **Fine-Tuning & Reinforcement Learning from Human Feedback:** if fine-tuning data or human feedback is inadequately vetted, the model might amplify inaccuracies rather than correct them. During RLHF, evaluators may unintentionally reward responses that sound correct instead of those that are correct;
- **Inference (Text Generation) Stage:** here is where hallucination becomes visible, as the model selects its next words based on probability rather than factual verification. When the model lacks sufficient context or attempts to answer beyond its knowledge, it tends to "fill in the gaps" with invented facts;
- **Deployment & User Interaction:** continuous user queries in the real world can expose new gaps in the model's training. Without proper safeguards

— such as fact-checking tools, citations, or human review —incorrect information can spread to end-users.

Hallucination starts from training process and occurs during inference, especially when the model encounters knowledge gaps. It presents a significant challenge, particularly in educational contexts where accuracy is essential.

3.2 The solutions

The hallucination problem has various approaches aimed at reducing its risks; however, from a personal perspective, one of the best ways to reduce its impact is to promote and raise awareness of this phenomenon. Informing the learners, educators, and the public at large about the concept of hallucination makes them to question, verify, and critically think about AI-generated outputs. By highlighting this problem - for example, through workshops, clear guidelines, or policy changes - people can be encouraged to think carefully about AI-generated information and make AI-based educational tools more reliable.

Addressing hallucination is crucial for enhancing the trustworthiness of GenAI usage in digital learning. The strategies to mitigate hallucination are focusing on data curation and pre-training improvements, model architecture and fine-tuning techniques, tools and metrics for detecting and monitoring hallucinations, as if follows:

Data Curation and Pre-Training Improvements

The training data quality is important for biases and hallucinations reducing in LLMs. An effective strategy is to implement data curation processes that prioritize high-quality representative datasets. It is important to have comprehensive data collection methods from various sources, able to minimize biases and improve the accuracy of generated content (Ji et al., 2023). Bias in training data can lead to wrong outputs and reinforce different stereotypes which nowadays society is trying to avoid. Maynez et al. found that training AI with a method called maximum likelihood can sometimes make the text it produces sound less natural or human-like. They suggest that by changing the training process a bit, we can get better results. They also point out that using fair methods to choose training data can help include voices that are often ignored, reducing bias in the final output (Maynez et al., 2020).

Model architecture and fine-tuning techniques

Using human feedback to train language models (RLHF) can make them more accurate and reliable. This method involves people reviewing the model's outputs during training, helping it focus on being correct rather than just sounding smooth. For example, research (Johnson et al., 2023) showed that this approach improved ChatGPT's accuracy in medical responses. Adding fact-checking steps directly into the model can also help catch errors as they happen.

Tools and metrics for detecting and monitoring hallucinations

Output checking of a language model for hallucinations is important. Researchers have created tools and tests to see if the generated text is correct. For example, the HaluEval test is designed to find errors or made-up facts in text (Li et al., 2023). While automated tests are useful, it is important for humans to check the output. (Svikhnushina & Pu, 2023) shows that online human reviews can provide detailed feedback on the model's performance. By using both automated tools and human reviews, researchers can better understand and reduce errors, which helps users have more confidence in the model.

3.3 The interest

To investigate the interest in "AI Hallucination," Google Scholar was used as data source. A keyword search for "Artificial Intelligence hallucination" was performed within specific publication years, ranging from 2016 to 2024. For each year, the number of search results returned was recorded, using these counts as a broad measure of academic and research attention on the phenomenon. While some publications might be counted more than once or might not be entirely about AI Hallucination, the overall trend provides a useful snapshot of how the term's usage and academic exploration have evolved. From Figure 2, it can be observed that the release of ChatGPT in 2022 is a likely inflection point: as large language models reached a broader audience, the phenomenon of hallucination garnered significant media and academic attention. Researchers began urgently exploring (in the Figure 2, it can be observed an exponential interest) how to identify, quantify, and mitigate erroneous outputs generated by AI tools now accessible to millions of users. As more people use tools like ChatGPT, deepseek, Claude, and others, the issue of AI making up information has become very noticeable. This has sparked both interest and worry among users.

Researchers and professionals in the tech industry have started to look closely at how AI "hallucinations" - instances when AI systems generate incorrect information - impact our trust and decision-making. The interest is in how these mistakes affect different domains, including education, and how these tools can be used in digital learning.

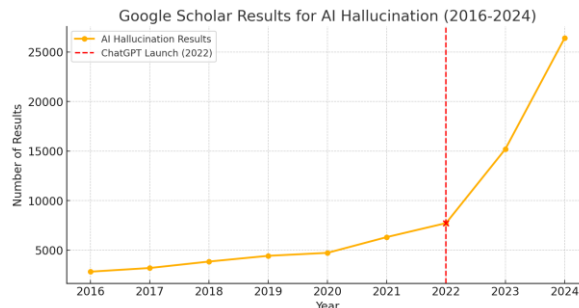


Figure 2. Google Scholar results

4. Conclusions

Generative AI is transforming digital education, creating new teaching methods that adapt to the needs of each student. By processing large amounts of data, new-era digital systems can create learning materials for each student's skill level and interest. In that way, education will become more equitable for students who have access to limited resources. Compared to traditional methods where the information is provided by teachers, generative AI can engage with learners by creating personalized study plans, and offer immediate help and feedback when they are required. This creates a real student-centered learning environment, making education more dynamic and responsive. When used correctly, these tools can work complementary with human teachers' capabilities, rather than replacing them. However, the benefits depend on how well teachers, schools, and students understand and control what AI can do.

A major concern is the AI capability to hallucinate. This means that AI models can create answers that sound real but are actually wrong or not based on evidence. If these errors go unnoticed, they can affect learners' trust and proliferate misinformation. Hallucinations have implications in different life cycle stages of a model:

- During training: the data used to train the AI can have errors or biases;
- In the fine-tuning phase: if the feedback used to improve the AI is incorrect;
- When used in real life: students may take a confident answer from the AI as fact, even if it is wrong. Also, if the models are learning from their interaction with users, they can be manipulated so they can learn incorrect.

As digital education is globally adopted, the risks associated with hallucination can have bad impact, especially in areas such as academic research where accuracy is essential. To reduce these risks, educators and students should double-check the information generated by AI. Schools can also add fact-checking tools or use peer review, performed by real teachers, to detect errors. It is important for both teachers and students to learn how generative AI works and what are the risks associated. Teachers must understand both the strengths and weaknesses of these tools, and students should question and verify the information they create by GenAI usage.

Schools and universities can include training on AI tools in teacher training. Also, considering that GenAI is not used only for school assessments, courses on how GenAI works should be designed and taught in schools, considering that they can address to students from primary schools to high schools and universities. Training should cover how to use AI effectively, identify potential errors, and understand how the data behind AI could influence output. In that way, educational institutions can create a culture of critical thinking.

In summary, when combined with human-in-the-loop methods, generative AI can be a trusted partner in modern education system. These tools will not replace human teachers, but will enhance their capabilities and help students learn as effectively as possible.

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Determination of Artificial Intelligence usage tendency in primary education

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Abstract: *This study aims to determine the inclination of studies on the use of artificial intelligence in primary education. The studies published in the Scopus database were analyzed with the bibliometric analysis method and the "distribution by year, citation status over the years, document type, distribution by country, keywords preferred by authors, and the most frequently used keywords in the title and abstract sections" of the mentioned studies were determined. The study, which was carried out to guide researchers and provide them with resources, found that papers on the use of artificial intelligence in primary education were first published in 1988. It was determined that the top cited studies were published in 2021. It was seen that the highest number of studies were carried out in China and article was the most preferred document type by the researchers. The keywords mostly used by the researchers in their studies were determined as "artificial intelligence", "education" and "Chatgpt". It was found that the most popular keywords in the title and abstract sections of the studies were "art", "mathematics", "professional development", "artificial intelligence integration", "primary school students", "Chatgpt integration and potential", "Stem", "ability", "perspective" and "computational identity".*

Keywords: Primary School, Artificial Intelligence, AI, Scopus, Bibliometric Analysis, Student, Teacher.

1. Introduction

It is observed that the area of artificial intelligence is gradually developing in information societies where 21st century skills are gaining importance. In the literature, it is stated that artificial intelligence, which deals with complicated and developing areas, provides a systematic approach for analysis of huge amounts of information (Padovano & Cardamone, 2024). Artificial intelligence, which was designed in the mid-1950s as a method to determine the intelligence of machines, has begun to be applied in other areas over time (Oliver, 2018). Stating that the idea of creating intelligent machines and artificial intelligence dates back to the 14th century, Humble and Mozelius (2019) emphasize that the field of artificial intelligence in education has left a significant impact in the last 25 years. Walan (2024) argues that debates on artificial intelligence intensified in late 2022 and

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affected various segments of society. Liang (2020) defines artificial intelligence as "a collection of information technologies based on machine learning" and states that its application in the field of education is making ground and will have a profound impact on education reform. Emphasizing that artificial intelligence has a high potential in the field of education, Hu et al. (2024) mention the benefits of artificial intelligence, including providing resources to teachers, improving the quality of teaching, encouraging personalized learning, and equipping students with efficient learning experiences. Similarly, Delgado de Frutos et al. (2024) underline that the most obvious benefit of artificial intelligence is streamlining teachers' work and providing access to resources. Dhara et al. (2022) explain that the integration of artificial intelligence into education provides advantages in education with features such as evaluating student performance, dividing students into groups according to their performance, improving performance, and facilitating class participation.

Artificial intelligence, which is considered extremely important for both students and teachers, was initially used at the university level. However, recent studies have drawn attention to the need to integrate artificial intelligence into primary education settings as well (Huang et al., 2024; Li, 2024; Yim, 2024; Ye et al., 2021). Similarly, interest in artificial intelligence education in primary schools is developing and studies are being carried out to design and develop effective artificial intelligence programs (Padovano & Cardamone, 2024; Gao et al., 2024). Artificial intelligence, which helps students cope with social, technological and environmental challenges (Chai et al., 2021) also provides support to teachers in fulfilling their duties in the education process, determining educational content and identifying educational needs (Alam, 2021). Considering the contributions of artificial intelligence technologies to the education process, it becomes clear that further research on this subject is required. The need for research on qualified research is developing on a daily basis, especially on the usage and development of artificial intelligence at primary education which has gained popularity in recent years. In this context, this study has aimed to determine the tendency for usage of artificial intelligence in primary education and to provide researchers with resources. Answers are sought to the following questions so as to realize the purpose of this study:

1. What is the distribution of studies by year?
2. What is the number of citations to studies by year?
3. What is the most preferred document type by researchers in their studies?
4. What is the distribution of studies by country?
5. What are the most widely used keywords by authors in their studies?
6. What are the most widely used keywords in the title and abstract sections of the studies?

2. Methodology

Scopus database was used to determine the trend towards the use of artificial intelligence in primary education. The research was based on a bibliometric analysis of data obtained from studies published in Scopus until 27.12.2024. The query was carried out using only the following keywords in the titles of the studies: “(TITLE (artificial AND intelligence AND primary AND education) OR TITLE (artificial AND intelligence AND primary AND school) OR TITLE (artificial AND intelligence AND primary AND teacher) OR TITLE (artificial AND intelligence AND primary AND student) OR TITLE (ai AND primary AND education) OR TITLE (ai AND primary AND school) OR TITLE (ai AND primary AND teacher) OR TITLE (ai AND primary AND student) OR TITLE (chatgpt AND primary AND education) OR TITLE (chatgpt AND primary AND school) OR TITLE (chatgpt AND primary AND teacher) OR TITLE (chatgpt AND primary AND student) OR TITLE (google AND gemini AND primary AND education) OR TITLE (google AND gemini AND primary AND school) OR TITLE (google AND gemini AND primary AND teacher) OR TITLE (google AND gemini AND primary AND student)”.

As a result of this query, 80 studies indexed in Scopus database between 1988 and 27.12.2024 were reached, and the data were downloaded as “Comma Separated Values (.csv)” and “Research Information Systems (.ris)”, which are formats supported for analysis by VOSviewer. “Microsoft Excel for Microsoft 365” software was used for the analysis of the obtained data for which graphics and maps were formed. In the study, donut chart and map visuals were created using Excel. In order to determine the keywords preferred by the authors and most commonly used in the title and abstract sections of the studies, VOSviewer bibliometric data analysis tool version 1.6.20 was employed (Van Eck & Waltman, 2010). <https://www.vosviewer.com/download>.

3. Findings

This section includes the findings obtained from the study.

3.1 Distribution of studies by year

Figure 1 gives the distribution of studies on the employment of artificial intelligence in primary education by year. According to Scopus data, the first study on artificial intelligence in primary education was conducted by Barnard ve Sandberg (1988) in 1988. This study discussed the results of CAI program usage in elementary school open sentence mathematics problems. However, no study was found between 1988 and 2018 on artificial intelligence in primary education. Only 1 study was conducted in 2018 on artificial intelligence in primary education, 2 studies in 2019, and 3 studies in 2020. 10 studies were carried out on the use of artificial intelligence at the primary education level in 2021, and the number of

studies increased to 13 in 2022. It is believed that Covid 19 pandemic played an effective role in the increase of number of studies on artificial intelligence after 2019. With the outbreak of Covid-19 pandemic, distance education applications gained popularity in the field of education and there has been a trend towards the use of digital tools. It is thought that this tendency directed resources to the field of artificial intelligence. 20 studies were carried out in 2023 whereas the number significantly increased to 30 in 2024.

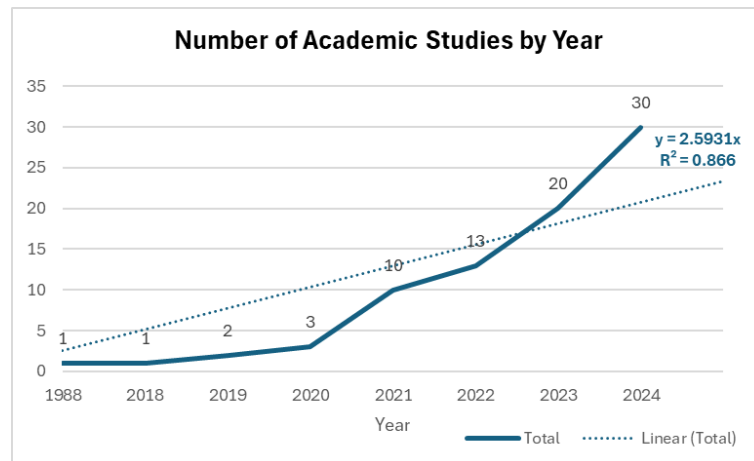


Figure 1. Distribution of studies on the use of artificial intelligence in primary education by year

3.2 Number of citations received by studies by year

Figure 2 gives the data obtained as a result of analysis conducted with the purpose of determining the number of citations made to studies by year.

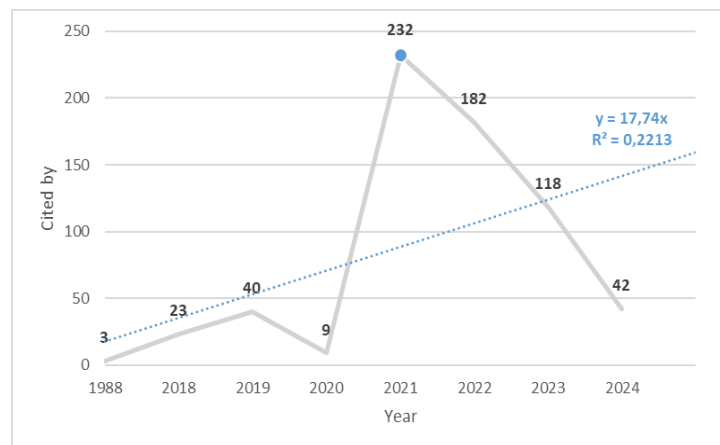


Figure 2. Distribution of citations by year

An examination of the studies conducted on the use of artificial intelligence in primary education shows that the highest number of citations are made to 2021 dated papers. Distribution of most cited studies by years reveals that the number of citations to studies conducted in 2021, 2022 and 2023 are 232, 182, and 118, respectively. The obtained findings show that the top cited paper is the study conducted by Chai et al. in 2021 with 124 citations, which examined the perception and behavioral intentions of primary school students towards learning artificial intelligence. It was determined that the second top cited study, with 85 citations, was conducted with the purpose of developing artificial intelligence literacy among primary school students and using digital stories by Ng et al. in 2022. The study by Lin et al. in 2021, which examined students' motivation to learn artificial intelligence, ranked third with 74 citations.

3.3 Distribution of studies by type of document

Examining the distribution of studies according to document type reveals that 54% of researchers prefer the article as document type in their studies ($f=43$) whereas 40% of researchers ($f=32$) prefer conference papers, 5% ($f=4$) prefer book chapters, and only 1% ($f=1$) prefer reviews. The distribution of studies according to document type is presented in Figure 3.

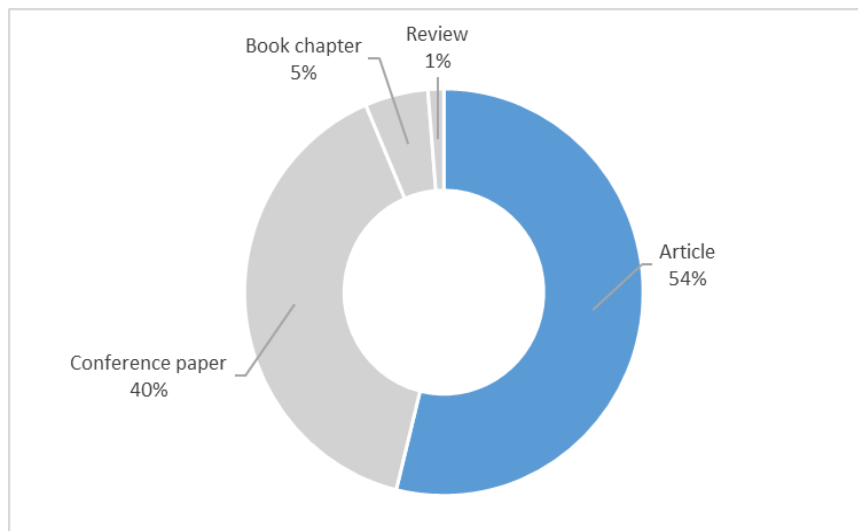


Figure 3. Distribution by document type

3.4 Distribution of studies by country

An examination of the distribution of studies conducted on the usage of artificial intelligence in primary education by country and region shows that China ranks first in terms of the number of studies ($n=39$). Hong Kong ranks second with 11 studies, while Australia, Spain and the United Kingdom each hosted 5 studies.

Taiwan contributed to the field with 4 studies, while 3 studies were conducted in the United States. A total of 29 countries were found to have conducted research on the use of artificial intelligence in primary education, and it was determined that only 1 or at most 2 studies were performed on this subject in most countries.

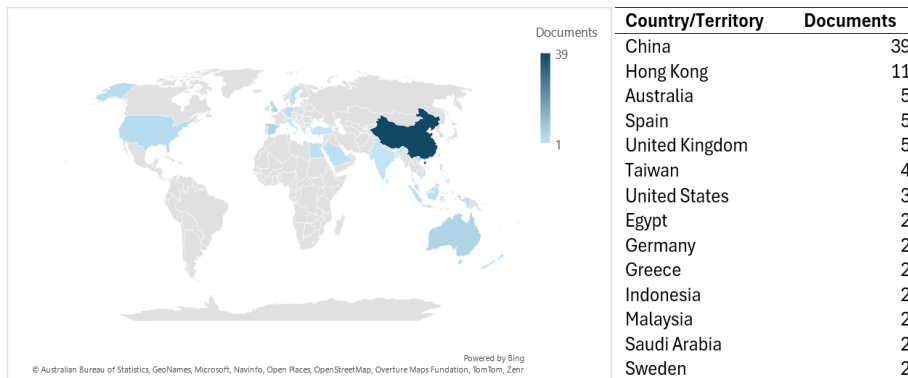


Figure 4. Distribution by countries

3.5 The most frequently used keywords by authors in their studies

In order to determine the most preferred keywords in the studies, the full counting method was used with VOSviewer to make calculations. In the study, the criterion was determined as "each keyword being used at least twice". As a result of the analysis, it was seen that the keywords were collected in 7 groups. It was determined that the most preferred keyword by the authors ($f=32$) was "artificial intelligence" with the connection strength of 36.

The second most preferred keyword in the studies ($f=6$) was found as "education" with a connection strength of 8. "Chatgpt" was the 3rd most frequently used keyword ($f=5$) and its connection strength was 7.

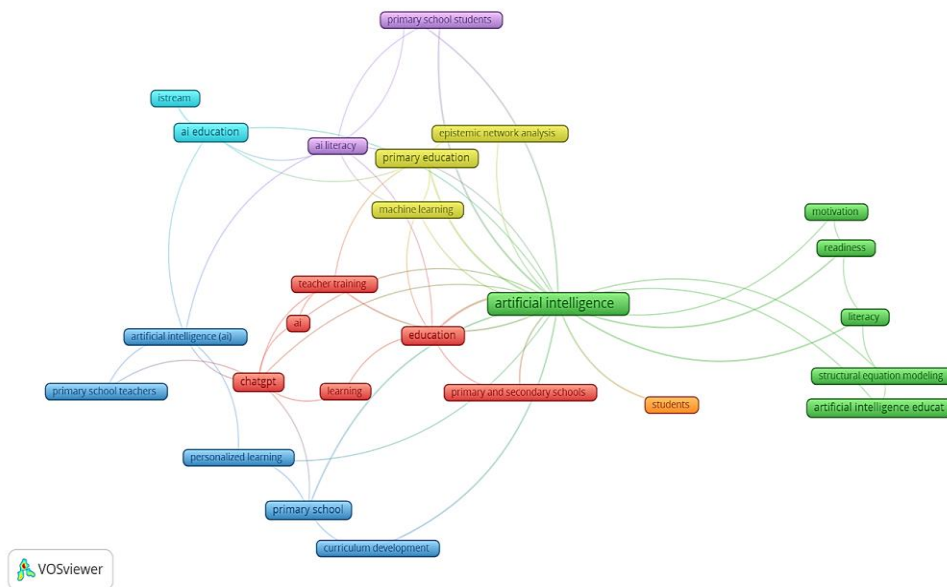


Figure 5. The most frequently used keywords by authors in their studies

When the clusters in Figure 5 are examined, it is seen that the green cluster reveals that the use of artificial intelligence focuses on variables such as motivation, readiness and literacy, and structural equation modeling was preferred as a method in examining these variables. As regards the red cluster, it is observed that the focal point is education and that the studies are conducted on the training of artificial intelligence. When the blue cluster is examined, it is seen that artificial intelligence studies focus on primary school teachers, curriculum development and personalized learning. Studies in the purple cluster were found to focus on artificial intelligence literacy in primary school students, and studies in the yellow cluster were found to focus on machine learning and epistemic network analysis in primary school.

3.6 The most frequently used keywords in the title and abstract sections of studies

In order to determine the most frequently used keywords in the abstract and keywords sections of studies, the use of a keyword for at least 5 times was preferred as a criterion. The calculation performed using full counting with VOSviewer method resulted in the grouping of keywords in 7 clusters. The obtained findings are given in Figure 6.

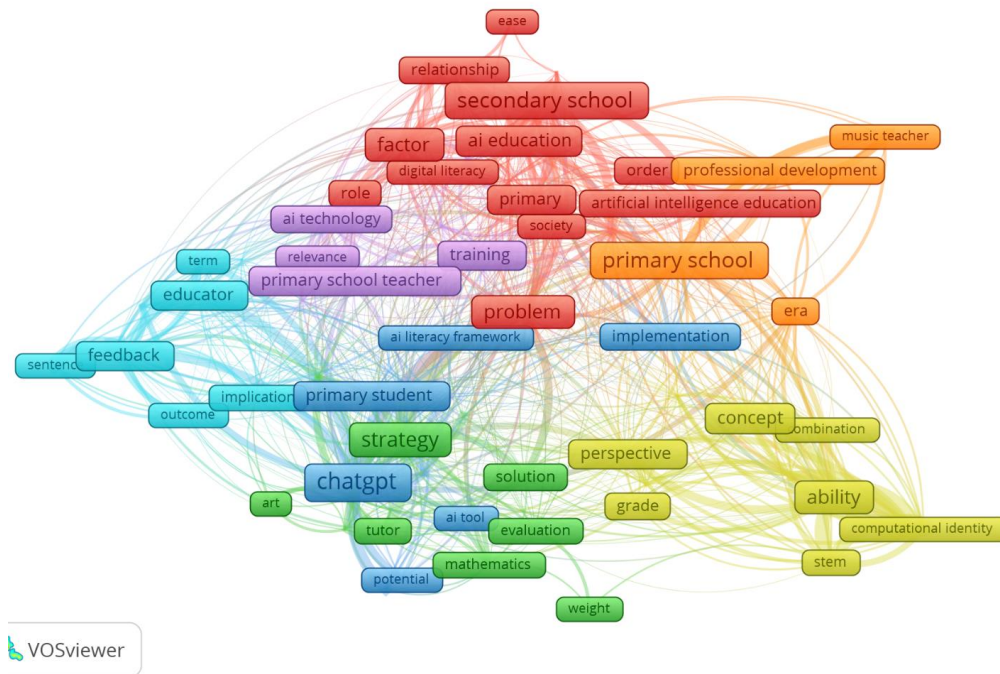


Figure 6. Most used keywords in the title and abstract section

The green cluster refers to problem solving and evaluation in education of arts and mathematics, whereas the orange cluster focuses on music teachers and professional development. It was found out that artificial intelligence is handled at elementary and secondary education levels together in red cluster, which examines the role of artificial intelligence in education, problem and digital literacy factors. The turquoise cluster includes studies examining feedback and outputs from instructors regarding AI integration. The blue cluster includes studies on primary school students, which also examine the integration and potential of Chatgpt as an AI tool. The findings reveal that the keywords in the yellow cluster include stem, perspective, ability, grade, and computational identity concepts.

4. Discussion and conclusions

This study determined the bibliometric analysis of studies on the usage of artificial intelligence in elementary education which are indexed in the Scopus database. Eighty studies published between 1988 and 2024 were examined, and it was found out that the highest number of studies were conducted in 2024. When the distribution of citations by year are examined, it was determined that 2021 was the year with the highest number of citations to these studies. Among the results obtained is that China is the country where the highest number of studies on the use of artificial intelligence in primary education are conducted. It was determined that the article document type was mostly preferred in the studies, and the keywords

“artificial intelligence”, “education”, and “Chatgpt” were frequently used by the authors. It was also found out that the keywords “art”, “mathematics”, “professional development”, “artificial intelligence integration”, “primary school students”, “Chatgpt integration and potential”, “Stem”, “ability”, “perspective” and “computational identity” were used in the title and abstract sections of the studies.

It is recommended that researchers who will conduct studies on the usage of artificial intelligence in primary education should take the results of this study into consideration.

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Exploring the integration of metaverse technologies in engineering education through the SAMR model

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Abstract: *The integration of the SAMR model (Substitution, Augmentation, Modification, and Redefinition) into metaverse-based learning environments has the potential to enhance student engagement and outcomes by transforming conventional educational practices into immersive, interactive experiences. It provides a framework for educators to integrate technology into teaching and learning processes. In the context of the metaverse, this model can be effectively applied to create dynamic and engaging learning experiences that transcend conventional methods. The paper justifies the selection of the SAMR model to plan the integration of metaverse technologies in the presence of CAVEs, and analyses the application of the new technologies at the different stages of the SAMR model. For each stage, the paper plans the tasks for students, possible scenarios, and the role of metaverse technologies. It demonstrates the successful implementation of the model in practice and provides examples of effective practices in the context of the CAVE (Cave Automatic Virtual Environment) metaverse. The metaverse is presented as a tool to improve the learning process and to promote innovative educational approaches. The final deliverable is a plan for phased integration of metaverse learning into a Python programming course following this model, building on existing best practices.*

Keywords: SAMR, Metaverse, CAVE, Python programming.

1. Introduction

Within the broader context of the accelerating digital transformation of education, the incorporation of innovative technological solutions into learning methodologies has evolved from a mere option to a critical imperative. The integration of technologies such as virtual and augmented reality presents unparalleled prospects for enhancing teaching and learning methodologies, with the potential to substantially enrich educational experiences. However, the effective implementation of these technologies necessitates the establishment of appropriate evaluation models to assess their impact on the learning process.

The SAMR model (Substitution, Augmentation, Modification, Redefinition) offers a pragmatic framework for evaluating the depth of technology integration in education. This model, developed by Dr. Puentedura, assists educators in the effective integration of technology into their teaching practices, thereby enhancing

educational quality (Romrell et al., 2014). As emphasised by Franco (2019), the SAMR model functions as a decision-making framework for educators adopting technology-driven instruction. The categorisation of technology use into four hierarchical levels, each representing a deeper pedagogical integration, is a key feature of the model (Romrell et al., 2014).

This paper examines the practical implementation of the SAMR model, highlighting its use in metaverse-based education, particularly within CAVE (Cave Automatic Virtual Environment) systems. It discusses the model's effectiveness in real-world educational settings and presents the metaverse as a tool for promoting innovation in teaching practices. Additionally, the paper proposes a phased integration plan for incorporating metaverse-based learning into a Python Programming course, structured according to the SAMR framework.

2. Materials and methods

This study explores the integration of metaverse technologies into engineering education, with a particular focus on their application in CAVE and Virtual Reality (VR) environments. These technologies offer innovative ways to create virtual spaces that facilitate the development of new learning scenarios and activities. The primary objective of this paper is to define the role of metaverse technologies within the SAMR model and plan their content accordingly. Under the MAGURA project, which is funding this report, we are building an immersive virtual reality laboratory based on an innovative approach for design, construction and control of the CAVE (Cave Automatic Virtual Environment). This laboratory will be a center for research, training and service, providing a controlled environment for students and faculty to conduct experiments, simulations and collaborative projects using the metaverse. High power Graphics workstation, Ultra short throw laser projectors, three wall stereo projection, Tracking system and separate interaction subsystems are used to implement this CAVE. Such a CAVE enhances functionality by providing immersive experiences, improved visual quality and optimized performance for a variety of applications on multi-user environments. Key Features of CAVE Technology are: Immersive 3D Projections; Real-Time Motion Tracking; Customizability and Interactivity; Integration of Advanced Technologies; Realism and Immersion; Dynamic Interaction; Cross-Disciplinary Use (Horan et al., 2018; Neupane et al., 2023).

The main objective of this paper is to define the role of metaverse technologies in the SAMR model and accordingly plan the content of the programming tasks through the implementation scenarios following the stages of the model.

A fundamental element of this planning process is the identification of potential learning scenarios and activities that can be incorporated into the metaverse, and the examination of how these scenarios evolve based on their level of integration within the SAMR model. The planned scenarios will be embedded

into the curriculum in a manner that ensures both a robust theoretical foundation and hands-on experience through metaverse-based learning. Rather than serving merely as a substitute for conventional teaching methodologies, the metaverse is envisaged as a catalyst for innovation in engineering education, with the potential to transform how students engage with and interact with the subject matter. In the context of acquiring competence in Python programming, the Jupyter Notebook plays a fundamental role in the learning process. As a web-based interactive computing environment, it allows for the creation, execution, and visualisation of Jupyter notebooks. IPython extends the standard Python console by offering features such as autocompletion, syntax highlighting, and efficient command management, and it supports magic commands — special functions that streamline the execution of common tasks — which enhance the overall learning experience. As the core of Jupyter Notebook, IPython enables interactive code execution, fostering an engaging and dynamic approach to programming. A significant benefit of Jupyter Notebook is its portability, which allows it to be used across various devices while also enabling seamless sharing and execution of documents on different computing platforms.

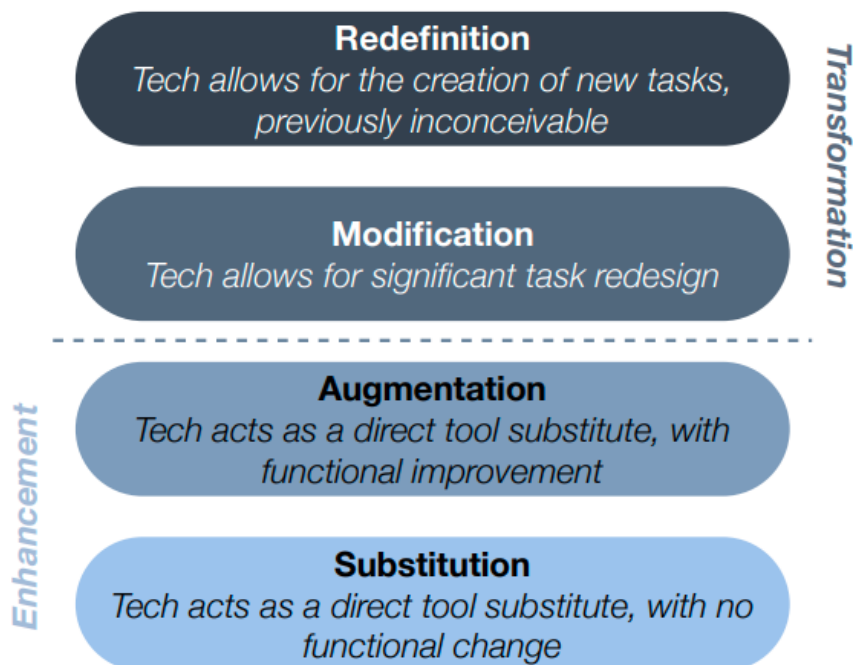
“Technological pedagogical and content knowledge (TPACK) is a dynamic framework for defining teachers' knowledge. This framework is needed for designing, implementing, and evaluating curriculum and instruction with technology.” (Mishra & Koehler, 2006; Taopan et al., 2020). The TPACK and SAMR frameworks are often used when new technologies are to be implemented or the outcome of their implementation is to be evaluated. While TPACK emphasizes the integration of technological, pedagogical, and content knowledge, SAMR in higher education is particularly known for its potential to increase student engagement and learning outcomes. SAMR is a framework that provides guidance and assists educators to categorize units of study and to contextualize and select appropriate ways to apply technology in a learning context. In this report, we apply SAMR to plan the units of study for the four levels of the framework. We intend to implement SAMR together with TPACK to provide a comprehensive framework for technology integration when CAVE is built for immersive virtual reality experiments.

SAMR Model consists of four levels (Figure 1): **Substitution:** Technology serves as a direct tool substitute, with no changes in functionality; **Augmentation:** Technology acts as a direct tool substitute but includes functional improvements; **Modification:** Technology enables significant redesign of tasks; **Redefinition:** Technology allows for the creation of new tasks that were previously unimaginable.

Substitution: At this level, technology is used as a direct substitute for a traditional tool without altering the nature of the task. The primary benefit is related to increased efficiency and convenience (Hamilton, Rosenberg & Akcaoglu, 2016). For instance, using a word processor instead of manually writing notes does not alter the task itself, but it facilitates its performance.

Transition from Substitution to Augmentation: Augmentation builds on substitution by adding new functionality that was not possible with the old technology, thereby rendering the task more efficient and engaging. Collaboration tools such as Google Docs, for instance, allow students to work in real time, encouraging collaboration and communication (Mishra & Koehler, 2006).

Transition from Augmentation to Modification: Modification signifies a shift in the nature of the task itself, with the introduction of new technologies resulting in substantial enhancements. At this stage, students are no longer merely engaged in the composition of reports; rather, they are undertaking the creation of multimedia presentations that encompass text, images, video, and sound. This modification fosters creative thinking and critical analysis (Hughes, 2005).



Rubén R. Puentedura, *As We May Teach: Educational Technology From Theory Into Practice*, (2009)

Figure 1. SAMR model (Puentedura, 2009)

Transition from Modification to Redefinition: The transformation phase represents the pinnacle of the SAMR model. This level is characterised by the ability to create tasks that were previously impossible, due to technological advancements. For instance, students can create virtual laboratories or conduct global experiments with peers from different countries through virtual reality, thereby transforming traditional education and opening up new possibilities for interactivity and collaboration (Kimmons, 2018; Puentedura, 2006).

The **SAMR model** is particularly well-suited for learning **Python programming** at the stage of integrating **CAVE and metaverse technologies** for several key reasons:

Firstly, its flexibility and adaptability. The SAMR model provides a structured framework for integrating new technologies into the learning process. Its strength lies in assessing the extent to which technology transforms education. In the context of Python programming, it enables a systematic introduction of metaverse technologies, ranging from basic substitutions of traditional methods (e.g., replacing physical classrooms with virtual environments) to the creation of entirely new learning experiences (e.g., immersive simulations where students can visualize their code in action). The model is particularly effective for disciplines that require both **practical application** and **creative problem-solving**.

Secondly, its role in aligning technology with the objectives of engineering education. The SAMR model helps evaluate the compatibility of new technologies with educational goals, ensuring their meaningful integration rather than mere adoption. In Python programming education, SAMR supports both **individual and collaborative learning** within metaverse platforms and CAVE environments. For example, in the **Modification and Redefinition** stages, students can work together in virtual laboratories, programming **interactive objects** and **real-time simulations**. This approach not only enhances engagement but also prepares students for the demands of future **industry applications**.

Thirdly, its ability to balance technological innovation with practical applicability. The model ensures that technology enhances, rather than disrupts, disciplines with **well-structured content**, such as programming. By maintaining this balance, SAMR facilitates an **effective, scalable, and future-oriented** approach to Python programming education.

3. Results and discussion

Integrating the SAMR model into metaverse-based learning environments can greatly improve student engagement and outcomes by transforming traditional educational practices into immersive and interactive experiences. In the metaverse, this model can be applied effectively to create dynamic and engaging educational experiences that surpass conventional methods. By using virtual reality and augmented reality, educators can create lessons that align with this model, transforming traditional learning into more engaging and effective experiences. This transformation fosters greater motivation and participation among students (Chen et al., 2024).

The model provides a framework for the development of technological-aided pedagogical plans, whereby the modus operandi of teaching and learning undergoes a progressive and incremental transformation. When applied to the context of teaching Python programming in a metaverse environment, this model

necessitates the development of scenarios that vary in terms of technology integration levels.

In order to facilitate programming in a virtual reality based environment, it is necessary to provide appropriate code input methods. Traditional keyboards and mice can be integrated into the environment via external devices, using tracking systems for their position and interaction. Alternatively, it is possible to use virtual keyboards and gesture commands. Exploring these methods and their effectiveness is a key aspect of developing VR-based educational programming platforms.

Students can also write the code at their workstations, regardless of their physical location. All participants will be represented in the virtual environment through their avatars. They will share and discuss their programming codes in CAVE, demonstrating the achieved functionality - driving virtual cars or drones. The virtual objects will represent the results of their Python programs, and the interaction between these objects - cars or drones - will take place directly in the CAVE environment. Implementation of this functionality is planned in future developments, in view of the initial stage of research and the imminent completion of CAVE.

Regarding the implementation of metaverse-based Python learning, no preliminary results have been obtained so far. The study is still in the conceptual phase and no tests have been conducted with students or trainers.

3.1 Substitution

The metaverse can replace traditional classroom settings with virtual environments, allowing students to attend lectures and participate in discussions through avatars, as seen in the creation of a Metaverse college environment (Sineka et al., 2024). The metaverse allows students to attend classes and access resources online. This basic level of integration can help maintain continuity in education, especially in remote learning scenarios (Chen et al., 2024; Puneet et al., 2024).

At the Substitution stage, the technology functions as a direct replacement for conventional methods, exhibiting no discernible functional enhancement.

- **Introduction to Python fundamentals:** Students utilise a metaverse environment to enter code that would typically be written in a standard development environment, such as the Jupyter Notebook.

- **Scenario:** At this level, it is not necessary to work in the metaverse and CAVE. The tools we have been using so far, such as <https://pythontutor.com/>, are sufficient. In this environment, students can understand the code and its operation, track the execution step by step, and visualize the memory status for Frames and Objects (Figure 2.).

The other approach is in a metaverse environment. Metaverse platforms are utilized to create virtual classrooms for delivering Python programming lessons.

This approach has the potential to replace traditional physical classrooms without requiring changes to the established teaching methodology. Students can work on tasks such as writing Python code for various programming assignments. The CAVE environment enhances both the development and execution of Python scripts, providing a more immersive experience while preserving the core characteristics of the assignments.

- **The metaverse role is as follows:** The metaverse environment functions as a visual-only alternative to the conventional interface.

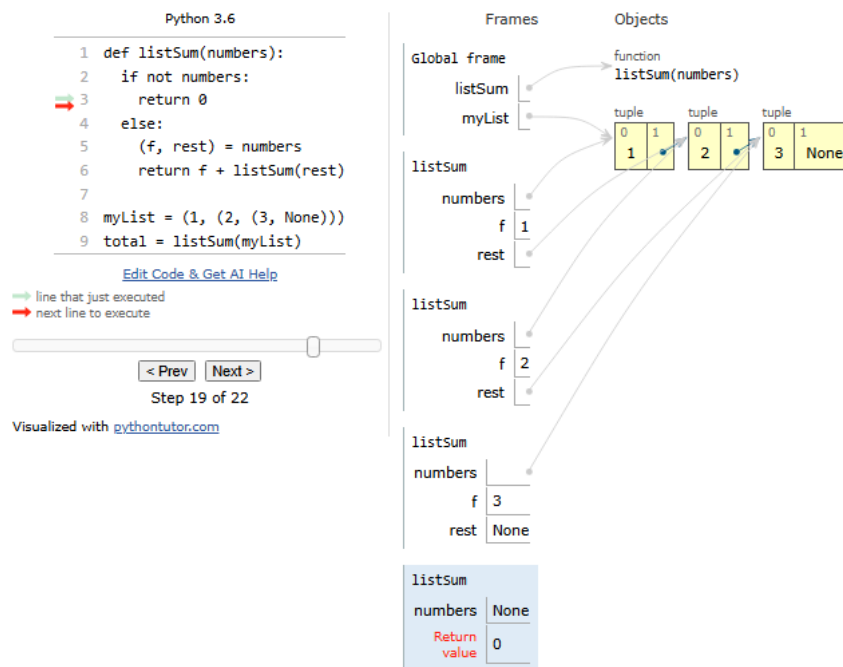


Figure 2. Python code visualization in <https://pythontutor.com/>

3.2 Augmentation

The use of VR glasses for attendance tracking and interactive quizzes enhances traditional educational practices by providing real-time engagement and feedback, thus augmenting the learning experience (Sineka et al., 2024). The metaverse enhances learning by incorporating multimedia elements such as 3D models and simulations, which can make abstract concepts more tangible and understandable. For instance, in STEM education, virtual labs can provide hands-on experiences that are otherwise difficult to achieve in a physical classroom (Singh et al., 2024).

The SAMR model, at the augmentation stage, has been demonstrated to facilitate functional enhancements over conventional methodologies.

- **Creating visualizations with matplotlib:** Specifically, students are able to develop programs that facilitate the visualisation of mathematical functions (e.g. sine and cosine) in a three-dimensional environment, thereby offering a novel and engaging way of presenting mathematical concepts.

- **Scenario.** At this second stage, the implementation of tasks can also be optional – in a long platform or in a metaverse environment. The integration of virtual reality or augmented reality within interactive coding environments serves to enhance traditional coding environments, thereby providing an interactive coding experience. Furthermore, the CAVE system has been shown to enhance the learning experience by providing real-time visualisation of Python program outputs. This can be particularly useful in areas such as data science or spatial analysis where visual feedback can aid understanding.

- **The function of the metaverse is as follows:** Visualisation in the metaverse improves concept understanding through spatial representation. Virtual reality headsets can enhance this by visualising code execution and debugging in 3D space. Tools such as IPython, an interactive Python environment, provide powerful capabilities for data analysis, code development and scientific computing. Within Jupyter Notebook, users can create and share interactive documents that integrate code, text, graphics, and other elements. This seamless integration promotes a comprehensive, cohesive approach to problem solving and knowledge representation.

3.3 Modification

The metaverse offers opportunities for significant redesign of tasks, particularly through the use of digital twins in cyber-physical systems education. This technology enables students to engage with complex systems in a virtual environment, providing a hands-on learning experience without the need for physical equipment (Yun et al., 2023). The metaverse enables collaborative projects and interactive activities that foster deeper learning. Students can work together in virtual spaces, engaging in problem-solving and critical thinking exercises that are enhanced by the immersive nature of the metaverse (Pangsapa et al., 2023; Singh et al., 2024).

The SAMR Model at the stage of Modification is planned to substantially revise the tasks.

- **Programming of simulations:** Specifically, students will be tasked with the creation of Python programs that facilitate interaction between objects within a metaverse environment.

- **Scenario:** Students are tasked with developing code to control the behavior of virtual objects. For example, a script can be designed to guide a virtual drone along a predefined trajectory. Python's suitability for interacting with objects in the metaverse environment is well established, enabling the simulation of movement

and control of virtual entities. One illustrative scenario involves directing a drone along a specified route using the pynput library to facilitate keyboard interaction and movement control. Alternatively, a drone can be programmed to navigate randomly within a 3D space by leveraging the random library.

- **The role of the metaverse in this context is pivotal.** The metaverse evolves from a mere platform to an active component of the learning process. Students can collaborate on Python projects in real time, sharing their code and engaging with virtual objects that represent diverse coding concepts.

3.4 Redefinition

The metaverse redefines educational possibilities by creating entirely new learning experiences. For instance, the use of explainable AI within the metaverse provides personalized feedback and improves learning outcomes, as demonstrated in drone education (Yun et al., 2024). Additionally, the integration of blockchain technology for secure and open learning communities represents a fundamental shift in how educational content is delivered and managed (Rodzin et al., 2024).

The metaverse creates entirely new tasks that were previously inconceivable (e.g., virtual reality experiences) (Krisbiantoro & Ashari, 2024; Ruíz-Contreras, 2024). For example, students can participate in virtual field trips or historical reenactments, providing experiential learning opportunities that enhance engagement and motivation (Pangsapa et al., 2023; Chen et al., 2024).

At the Redefinition stage of the SAMR model, the creation of new tasks that were previously impossible is associated with the process.

- **Interactive tasks adapted to the metaverse environment with CAVE:** Students are tasked with the development of Python-based immersive simulations that facilitate real-time interaction between actors in disparate locations.

- **Scenario:** As part of the Metaverse Integration course, participants will use Python to program a traffic simulation in an urban environment, allowing interactions between objects (e.g. cars) and different scenarios. Metaverse Integration: These simulations can be extended using libraries such as the Unreal Engine Python API or Unity ML Agents to enable real-time interaction with 3D objects. The Pygame library is used to introduce the basics of simulation by visualising and processing interactions. In this environment, participants control virtual vehicles while Python-driven traffic elements dynamically respond to traffic lights, pedestrians and congestion.

Redefining learning with CAVE: CAVE enables immersive learning experiences by allowing students to develop and interact with complex 3D models and simulations beyond the capabilities of standard screens. This includes the procedural generation of structures using Python scripts that can be visualised and manipulated within the CAVE.

- **The function of the Metaverse is as follows:** The Metaverse functions as a medium for collaboration and innovation, significantly enhancing the learning process. At this stage of the SAMR, the development of a virtual laboratory becomes a viable proposition. Students are able to write Python scripts with the objective of manipulating virtual robots or simulating real-world scenarios. The utilisation of tools such as Blender for visualisation and Geometry Nodes for rendering can enhance the visual representation of Python-generated models.

The metaverse presents promising applications in education, especially in blended learning, language acquisition, competency-based education, and inclusive education (Zhang et al., 2022). The research highlights the importance of social interactions and flipped classroom methods in promoting engagement. It posits that integrating the SAMR model with these pedagogical approaches can potentially enhance student outcomes within metaverse environments (Pangsapa et al., 2023). Integrating the Metaverse into both STEM and HASS subjects has been shown to enhance learning outcomes through student-centered methods like problem-based learning (Mohamed, 2022).

The integration of the SAMR model within metaverse-based learning environments presents numerous advantages. Nonetheless, challenges such as the necessity for a robust technological infrastructure and comprehensive educator training must be addressed to maximize the potential of this approach. It is imperative to ensure that educators possess the requisite skills and resources to implement these technologies effectively, as this is vital for achieving the intended educational outcomes (Kurniawan & Sutabri, 2024; Chen et al., 2024). Moreover, the existing literature highlights a significant gap in the theoretical framework for creating immersive lessons in the metaverse that includes a pedagogical model (Singh et al., 2024).

4. Conclusions

The use of the SAMR model to teach Python programming in a metaverse environment involves creating scenarios that incorporate varying levels of technology integration. This paper provides illustrative examples of this application. In this study, we explicitly point to the lack of experimental validation through practical tests with students and faculty as a limitation. This will be done in our future research upon completion of CAVE.

The following ideas for future research can be successfully implemented, including integration with other technologies. The selection of platforms and the subsequent testing of their functionality and compatibility are pivotal considerations. Furthermore, it is imperative that educators are acquainted with best practices for operating within the metaverse environment and are trained to utilise novel tools and technologies, including Python programming in metaverse platforms.

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An ontology of knowledge components in the domain of Artificial Intelligence

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Abstract: *In today's AI-driven world, business professionals need to understand the impact of Artificial Intelligence in both their industry and their professional activity and specific domain. But what factual, conceptual, procedural and meta-cognitive knowledge components do managers need to acquire such as to be more effective in their job? Not only what exactly do they need to understand but what tools can they use out of this very large domain of knowledge? In this paperwork we present an implementation of an ontology of knowledge components in the domain of Artificial Intelligence by using Neo4j knowledge graphs and how this can be used in the process of AI managerial competency development.*

Keywords: Ontology, Knowledge Graph, AI Competency Framework.

1. Introduction

This paper is part of a wider research in the domain of developing AI-enabled training tools for business professionals, more specifically a journey of developing an adaptive Intelligent Tutoring System to be used as a tool for training business management professionals in the domain of Artificial Intelligence (Negura & Ionescu, 2024).

In this paper we are describing our approach to modelling the Artificial Intelligence knowledge domain, namely an ontology of knowledge components in the domain of AI that will serve as one of the core components of the Intelligent Tutoring System. The ITS's main function is to understand each learner's knowledge state and provide the most appropriate support in facilitating the development of AI competencies in line with his/her learning objectives.

Since the ontology is developed with this end goal in mind of serving as a knowledge base for the implementation of an adaptive learning algorithm targeted at business management professionals, concepts included in the ontology and their relationships are selected to be relevant given the needs and requirements of this specific target group. Furthermore, we also introduce in our resulting knowledge

graph a Competency Framework that groups the knowledge components in specific competencies fit for each managerial role and seniority level.

According to the European Commission's Joint Research Centre (JRC) JRC121897 Technical Report on labour, education and technology competence is defined as "*a general ability to do well in a particular task domain*" (Rodrigues, Fernández-Macías & Sostero, 2021). This level of task domain competence is attained by learning and developing a mix of knowledge, skills, and attitudes specifically relevant to each business role (Rodrigues, Fernández-Macías & Sostero, 2021/02).

2. Taxonomies and ontologies in the domain of AI today

Many taxonomies and ontologies are built and used today especially with the rise of semantic networks and knowledge-based intelligent services. The World Wide Web Consortium (W3C) defined a common data model for interoperability between knowledge management systems called Simple Knowledge Organization System (SKOS) (Consortium, SKOS Reference, 2025).

2.1 Definition of taxonomy

Taxonomy is defined as "*the science of classification*" (Britannica, 2025) and is historically linked to the classification of biological entities. The term is derived from the Greek *taxis* ("arrangement") and *nomos* ("law") thus meaning the law of arrangement (based on specific criteria, but mainly in a hierarchy of classes from the most generic to the more specific categories/groups).

The most famous taxonomy in the field of learning is Bloom's „taxonomy of educational objectives" (Bloom, 1982) originally published in 1956, and revised in 2000 (Anderson, Krathwohl & Bloom, 2000).

In business, a taxonomy is „a hierarchical framework used to categorize, classify, and group similar concepts, terms, and entities into categories and subcategories" (Times, 2025) (E.g., specialization (is-a) taxonomies, composition (part-whole) taxonomies).

2.2 Definition of ontology

Ontology is defined as "the philosophical study of being in general, or of what applies neutrally to everything that is real" (Britannica, Ontology, 2025). In knowledge management an ontology "encompasses a representation, formal naming, and definitions of the categories, properties, and relations between the concepts, data, or entities that pertain to one, many, or all domains of discourse" (Ontology (informatics science), 2025).

Domain ontologies are constructed by identifying classes of objects/concepts and relationships among them (e.g. triplets of Subject – Verb – Objects). They are

written in standardized formats using languages like the Web Ontology Language (OWL) (Consortium, 2025) and respecting standard data models like the Resource Description Framework (RDF) as per the specifications of World Wide Web Consortium (W3C).

2.3 Known AI ontologies

Some of the relevant ontologies in the domain of Artificial Intelligence in use today are:

- pedagogical/learning ontologies: SMARTIES (Mizoguchi & Bourdeau, 2000), (Hayashi, Bourdeau & Mizoguchi, 2009),
- ontology of AI Innovation: InnoGraph AI (Alexiev, Bechev & Ositsyn, 2023) (Massri, 2023).

3. Methodology

In designing the current AI ontology, we started from Bloom's taxonomy of educational objectives (Bloom, 1982) and followed our end goal of developing a model of the AI domain of knowledge fit for the purpose of supporting the development of AI competencies by business management professionals.

As such, the principles we followed in the development of this ontology were:

1. relevance: include the fundamental knowledge components that any business professional should be aware of and use in their professional activity, regardless of their main field/domain of expertise.
2. accessibility: group knowledge in a manner that allows non-technical professionals to gradually understand the concepts and adopt AI services in their specific area of expertise.
3. granularity: define knowledge components at a granular level that allows flexible grouping and use in different learning strategies.
4. completeness: include a set of knowledge components that reasonably covers the domain of AI and its corresponding subdomains.

We started by decomposing the factual, conceptual, procedural and meta-cognitive knowledge (Bloom, 1982) in the domain of AI in atomic knowledge components (Dai, Hung, Tang, & Li, 2021). For doing this, we have first built a dictionary of knowledge classes – see Table 1 – and then assigned each one of the specific knowledge elements in the domain of AI to its corresponding knowledge class.

Table 1. A dictionary of knowledge components classes in the domain of AI

Knowledge Category	Class	Definition
MetaCognitive	Concept	understand the prerequisites, what one needs to know, and set-up the right expectations (e.g. expected learning progress rate)
MetaCognitive	Technique	how to approach learning
Factual	Fact	A piece of information that can be proven to be true or false based on evidence.
Factual	Event	An occurrence or happening, especially one of significance.
Factual	Person	An individual human being.
Factual	Publication	A work that has been published, such as a book, journal, or article.
Factual	Organization	A group of people structured and managed to meet a collective goal.
Factual	Product	An item or service that is created and sold in the marketplace.
Factual	Intelligent System	A system that uses AI to perform tasks that would typically require human intelligence.
Conceptual	Term	A "term" is a word or a group of words that has a specific meaning within a particular context or field of study.
Conceptual	Concept	A "concept" is an abstract idea or a mental representation that encapsulates a general notion or category. Concepts serve as the building blocks for thoughts, allowing us to categorize, interpret, and communicate about various phenomena, objects, or relationships.
Conceptual	Classification	The process of grouping items based on shared qualities or characteristics.
Conceptual	Infrastructure	The basic physical and organizational structures needed for the operation of a society or enterprise.
Conceptual	Architecture	The art and science of designing and constructing buildings; also refers to the structure of any system.
Conceptual	Category	A group or class of items sharing common characteristics.
Conceptual	Methodology	A system of methods and principles used in a particular discipline.
Conceptual	Framework	A basic structure underlying a system, concept, or text.
Conceptual	Model (AI)	A representation of a system or process that uses AI to simulate or predict outcomes.
Conceptual	Rule	A prescribed guide for conduct or action; an authoritative regulation.
Conceptual	Principle	A fundamental truth or proposition that serves as

		the foundation for a system of belief or behavior.
Conceptual	Regulation	A rule or directive made and maintained by an authority.
Conceptual	Technology	The application of scientific knowledge for practical purposes, especially in industry.
Conceptual	Theory	A supposition or a system of ideas intended to explain something.
Conceptual	Domain	An area of knowledge or activity.
Procedural	Language	A formal language comprising a set of instructions used in computer programming to implement algorithms and manipulate data structures, that produce various kinds of output.
Procedural	Library	A collection of functions used in computer programming (language-specific).
Procedural	Technique	A way of carrying out a particular task, especially the execution of an artistic work or a scientific procedure.
Procedural	Method	A procedure, technique, or way of doing something, especially according to a plan.
Procedural	Process	A series of actions or steps taken to achieve a particular end.
Procedural	Procedure	An established or official way of doing something.
Procedural	Algorithm	A process or set of rules to be followed in calculations or other problem-solving operations, especially by a computer.

The **Factual Knowledge** category contains classes like *Person*, *Organization*, *Event*, *Product*, and so on (see Table 1). These are both domain specific and factual in nature. The elements in these classes can generally be learnt / memorized being part of the theoretical dimension of the AI knowledge domain. Knowledge components in these classes need to be remembered and understood in order to be used in higher-order cognitive processes.

- Key contributors in the domain of artificial intelligence were assigned to the *Person* class. These are both scientists that proposed key concepts, theories, models, network architectures and so on, or public images of companies active in the domain (e.g. Sam Altman of OpenAI);
- Descriptions of AI-driven products like ChatGPT, Copilot, Gemini and so on were assigned to the *Product* class;
- AI-enabled notorious Intelligent Systems like AlphaGo, Deep Blue, Mycin and so on were assigned to the *Intelligent Systems* class;
- Companies, AI associations or other educational institutions active in the domain of AI were grouped under the *Organization* class.

Few other important factual knowledge classes refer to *Facts*, *Trends* and/or sources of information in the domain of AI like *Publication*, *Source*, *Book* or *Case Study*. These are all extremely useful in the process of learning, especially with our

purpose in mind to develop adaptive learning algorithms that adapt the process to the specifics of each individual learner.

The **Conceptual Knowledge** category includes classes like *Concept*, *Classification*, *Theory*, *Methodology*, *Framework*, *Model*, *Architecture*, *Infrastructure*, and so on (see Table 1). These are also specific but more abstract and conventional (agreed within the community of practice). The elements in these classes also require memorization and proper understanding and involve higher-order cognitive processes.

- Definitions of terms (“What is...?”) were grouped under the *Term* and/or *Concept* classes part of the Conceptual Knowledge category,
- Other key concepts like classifications, sub-domains of the artificial intelligence knowledge domain, main principles, theories, methodologies, network architectures, regulatory acts (e.g. EU AI Act) and so on, were assigned to the corresponding specific classes in the Conceptual Knowledge category.

The **Procedural Knowledge** category includes classes like *Algorithm*, *Procedure*, *Method*, *Technique* and so on (see Table 1) that describe practical/procedural knowledge to be applied in higher-order cognitive processes like use/apply, analyze, evaluate or create new knowledge. Developing new skills is based on the proper use of such procedural knowledge in the context of the tasks and challenges specific to each managerial role.

- The main procedural knowledge components in the domain of Artificial Intelligence were assigned to classes like *Algorithms* (e.g. regression, classification, k-means, support vector machines, etc) *Procedure* and *Technique*;
- Definitions and links to programming languages like Python or R are assigned to the class called *Language*;
- Corresponding programming language libraries are assigned to the *Library* class. This differentiation of libraries from programming language (the *Language* class) allows for higher flexibility in using the ontology for upskilling / learning recommendations.

The **Metacognitive Knowledge** category is extremely important for the process of competence development. It covers several aspects of learning and training like: *Concepts* (e.g. “*know what one needs to know in the domain of AI*”) or learning *Techniques* (e.g. “*how to approach learning in the domain of AI*”).

4. Results

The resulting ontology and thus the entire relevant knowledge in the AI domain were coded in a knowledge graph (Singhal, 2012) using the Neo4J tool (neo4j.com) with the consideration of relevant classes and relationships defined in the earlier stages.

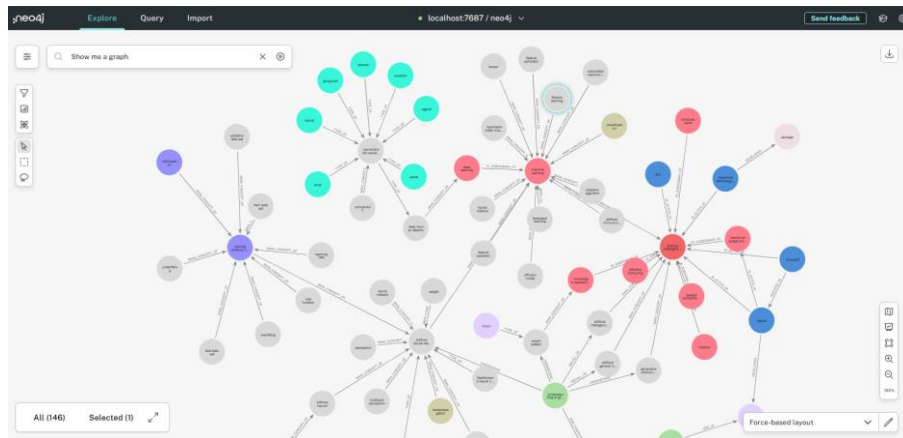


Figure 1. AI knowledge domain

Each node in Figure 1 above represents a specific knowledge component in the AI knowledge domain, an object of a specific type (class). The color of the node represents the class (each class is represented by a different color in the graph). Relationships between nodes are displayed as connecting links (edges) with the name on the link representing the nature of the relationship (e.g. TYPE_OF, or MAIN_CONCEPT_OF).

The knowledge graph (KG) is a very flexible structure that can be easily extended with new classes and relationships. Moreover, additional relationships can be added between the nodes in the graph (existing and/or new) and both nodes and relationships can be assigned properties to store class-specific attributes.

The Neo4J knowledge graph allows us both to reason and operate with knowledge in the AI knowledge domain by using the Cypher Query Language (<https://neo4j.com/product/cypher-graph-query-language/>). As such, the graph can be used as the knowledge domain model in an Intelligent Tutoring System (ITS).

5. Discussions

Once we developed this flexible model of knowledge in the domain of Artificial Intelligence, we extended the knowledge graph with a couple of new classes so that we can use it in the process of managerial upskilling.

In a separate phase of our research, we developed an AI-competency framework fit for the purpose of upskilling management professionals. The framework contains both AI Fundamental competencies (e.g. understanding of general AI concepts and the AI ecosystem, organizing AI-based business processes, principles and ethics in AI, Ai regulation and basic use of AI tools) as well as higher order AI competencies specific to the planning, organizing, leading and controlling functions at various management levels.

A *Competency* class was added to the KG to accommodate the definition of specific managerial competencies required in business – see green nodes in Figure 2. This allows us to overlay an entire competence framework on top of the AI domain model and link each competency to its corresponding knowledge components in the knowledge domain. Since a competency is defined as the collection of knowledge, skills, attitudes and other personal characteristics that allow a manager to be performant in his/her role (Spencer & Spencer, 1993) each competency is linked to both the factual and conceptual knowledge components but also to procedural knowledge that allows a manager to use the relevant procedures, methods, algorithms and techniques in solving the tasks and challenges specific to the role.

A *Lerner* class was also defined and added to the graph to store information about the learners including several profiling properties: age, gender, socio-professional attributes (role, employer/company) or psychological profiling attributes relevant to the learning process. This class allows us to define each learner as a node in a corresponding knowledge graph and trace his/her development in time but this is outside the scope of the current paper.

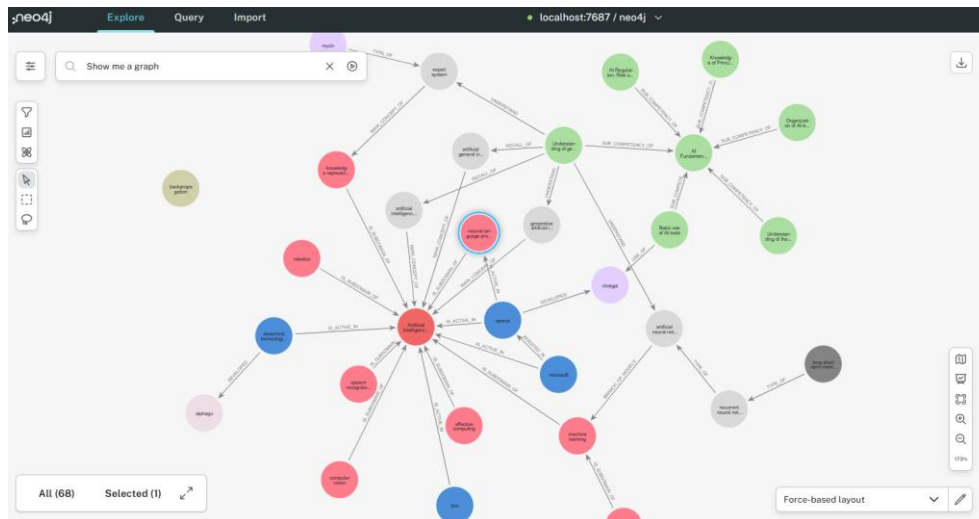


Figure 2. AI knowledge domain

6. Conclusions

Knowledge graph (KG) technology allowed us to develop a model of the AI domain of knowledge that can be used in several applications. While we constructed the graph manually, today's AI models, especially the LLMs, and techniques (e.g. Name Entity Recognition) allow automation of the process of expanding the KG with additional classes and/or knowledge components.

Moreover, frameworks like the LangChain allow easy integration of the KG both in applications developed in several programming languages (e.g. Python,

Java, etc.) as well as linking the KG to LLMs in a Retrieval Augmented Generation (RAG) configuration.

A topic of further exploration is the specific algorithms that should be used in tracking the progress of each learner throughout the process of developing the target competencies (a.k.a. “knowledge tracing”).

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Virtual education with 3D bread models

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Abstract: *This paper presents how 3D scanning technology can be integrated into food technology education, considering the study of the properties of bread with functional additives included in it. Using a pedagogical approach to apply 3D scanning technology in education leads to increased engagement and formation of critical thinking in students. The proposed methodology is a way to show students how data can be dynamically changed and the results obtained can be evaluated. 3D technology contributes to determining the quality, packaging, and structural changes in food products with sufficiently accurate and reproducible data. Further research aims to integrate with AR (augmented reality), virtual platforms for remote experimentation, and advanced learning resources.*

Keywords: 3D Scanning Technology, Food Technology, Bread Analysis, Pedagogical Strategies.

1. Introduction

The integration of technology with education opens up opportunities for new and interactive learning experiences. Among the innovative technologies is 3D scanning, which has emerged as a tool that allows educators to transport real objects into digital space.

According to a study by Reisoğlu et al. (2017), collaborative and inquiry-based learning strategies are more commonly used in 3D virtual learning environments. Presence, satisfaction, communication skills, and engagement have been repeatedly studied as emotional and cognitive outcomes. Language learning and science are also widely discussed topics.

In the study by Uyar et al. (2009), the authors point out that 3D scanners simplify the geometric characterization of irregularly shaped food products, such as pears and strawberries, by creating accurate digital 3D images. This reduces labor, reduces measurement errors, and improves simulation accuracy when imported into computational fluid dynamics (CFD) programs, making 3D scanning a suitable tool

for food engineering. This thesis is further developed by Yang et al. (2010), who state that 3D laser scanning technology allows for sufficiently precise, fast, and efficient measurement of food product volumes. By generating 3D data from a point cloud, it simplifies inventory management and provides high accuracy, making it a practical tool for detecting reserves, for example, in granaries.

Rodriguez-Parada et al. (2018) highlight the potential of 3D scanning and reverse engineering in the food industry within the framework of Industry 4.0. By digitizing fresh food, personalized and sustainable packaging can be designed with precision, reducing material use and increasing product safety. The method improves efficiency, supports the development of competitive products, and opens up opportunities for additive manufacturing and augmented reality applications. Gulak et al. (2019) introduce a high-resolution UV laser marking system for plastic products, such as food caps, offering safer, faster, and more precise marking without harmful additives compared to conventional methods. The system enables dynamic, high-speed marking, improves product protection with 3D scanning and dual-lane laser systems, and outperforms traditional printing methods in quality and efficiency.

Bread is an everyday staple that is a hot topic for research. The fact that this product can be transformed into detailed 3D models makes it possible to create tactile and realistic experiences in a virtual learning environment. A particularity of bread is that it is a product with a relatively short shelf life and can hardly be used in education every school year. This is largely true for bread that is under research, for example, with different percentages of functional additives.

Different manufacturers of 3D scanners, such as Matter and Form, Creaform, and Artec 3D, offer a range of educational resources to facilitate the use of their devices. Matter and Form (Matter and Form, 2025) offers a professionally developed curriculum and a library of resources for educators to help learners develop the competencies they need in 3D scanning. Meanwhile, Creaform ACADEMIA (Creaform, 2025) offers a full range of 3D measurement technologies, including e-learning courses for hardware and software. Artec 3D (Artec Europe, 2025) enhances training by providing 3D scanning tools in a variety of applications. Stable Micro Systems (Stable Micro Systems, 2024) offers 3D scanners for measuring bread and bakery products. The manufacturer also offers educational resources related to their devices. Their Volscan Profiler is a desktop laser scanner for volume, density, and dimensions of bakery products; accurate assessments are provided for quality control and product development. The educational materials provided by Stable Micro Systems help users understand the operation and benefits of the Volscan Profiler, thus making it valuable to bakers and food scientists in their goal of high bread quality.

From the analysis of available literature sources, it can be summarized that in most cases, general-purpose 3D scanners are offered, which can be used in bread analysis. There are few manufacturers of specialized devices suitable for solving

tasks in this area. Training resources are related to how to work with 3D scanning devices. It is necessary to conduct additional research related to training in the analysis of three-dimensional images of bread, especially in the field of the influence of various additives in the product.

The aim of this work is to integrate 3D scanning technology to improve food technology training. An approach is proposed in which, by integrating the 3D scanning process, realistic models are created and the properties of bread with functional additives are analyzed.

2. Pedagogical approach and didactic solutions in 3D scanning of bread

2.1 Pedagogical approach

Three pedagogical approaches are suitable for teaching 3D bread scanning. The first is multimedia learning (Tee et al., 2019), which improves engagement by incorporating different types of digital resources, such as videos, interactive tutorials, and e-books, that help learners learn how to perform the scanning process in a sufficiently accessible way. An experimental method (Kvittingen et al., 2016) identifies which variables affect scanning accuracy by actively learning the technology. The demonstration method (Bonjour et al., 2014) is visual and interactive. Learners are observers but also participate in the scanning process and thus easily understand the step-by-step actions that need to be performed for a successful 3D scan.

Multimedia learning. Multimedia-based learning uses a combination of video, audio, interactive elements, and other digital resources to enhance the learning process. In 3D bread scanning, multimedia engages students in ways that a traditional lecture cannot. For example, through interactive tutorials, video instructions, interactive e-books, and e-tests.

Experimental method. This method involves testing hypotheses and exploring new theories. When using this approach to 3D bread scanning, an experiment is structured that allows students to hypothesize about the factors affecting the accuracy of 3D bread scanning. Also, to plan an experiment, such as evaluating the impact of different additives on the geometric characteristics of bread. Scanning the bread, collecting the resulting data, and processing it using various algorithms to process the 3D images of bread. The final step is analyzing the results obtained.

Demonstration method. This method involves showing objects and materials to students while explaining. In 3D bread scanning, a demonstration is used to visually understand the scanning process and how this technology is applied to bread. The demonstration of the scanning process discusses the capabilities of different types of 3D scanners and their applicability according to the texture and shape of the bread. The steps that are performed to realize the scanning of the bread

are indicated sequentially. The scanning process is demonstrated in real time (scanning of a loaf of bread). Interactive demonstration—the students take part in the individual stages of scanning the bread.

2.2 Didactic challenges and solutions

The complexity of geometric modeling training stems from the requirements for mastering mathematical shapes and transformations, which can be difficult for learners. Also, limited training time leads to insufficient practical exercises, which further complicates the process (Pisarova, 2024). These challenges can be overcome by simplified 3D scanning workflows and the use of pre-prepared models.

An interdisciplinary approach is important in education, uniting different scientific fields (Neminska, 2023). In the case of 3D scanning of bread, it is demonstrated how food science, computational modeling, and technological education are connected, which is facilitated by studying algorithms for processing 3D images of bread (Uyar et al., 2009).

Assessing learners' skills in problem solving, collaboration, and digital literacy is an important part of the educational process (Neminska, 2023). In this regard, the use of 3D scanning for educational purposes provides an opportunity to develop and assess these skills.

Table 1 summarizes the didactic challenges and their solutions from the perspective of education through 3D scanning of bread.

Table 1. Didactic challenges and solutions

Challenge	Solution
Complexity of 3D Modeling Training	Using simplified 3D scanning workflows and pre-prepared models
Short Shelf Life of Bread as a Learning Material	Creating reusable 3D printed models
Interdisciplinary Integration	Demonstrating how 3D scanning connects food science, computational modeling, and technology education and learning algorithms for processing 3D images of bread
Evaluation of Learning Outcomes	Assessing learners' problem-solving, collaboration, and digital literacy skills

3. Results

As a result of the studies and summaries, an algorithm and procedure for 3D scanning of bread with functional additives was created.

The flour bread was prepared according to technology based on the approved standard US02/2011 (Approved Standard "Bulgaria," "white" bread). The main raw material, wheat flour, was replaced with 3,7% pigweed flour and 7,1% purslane flour.

The amount of additives was determined through preliminary studies.

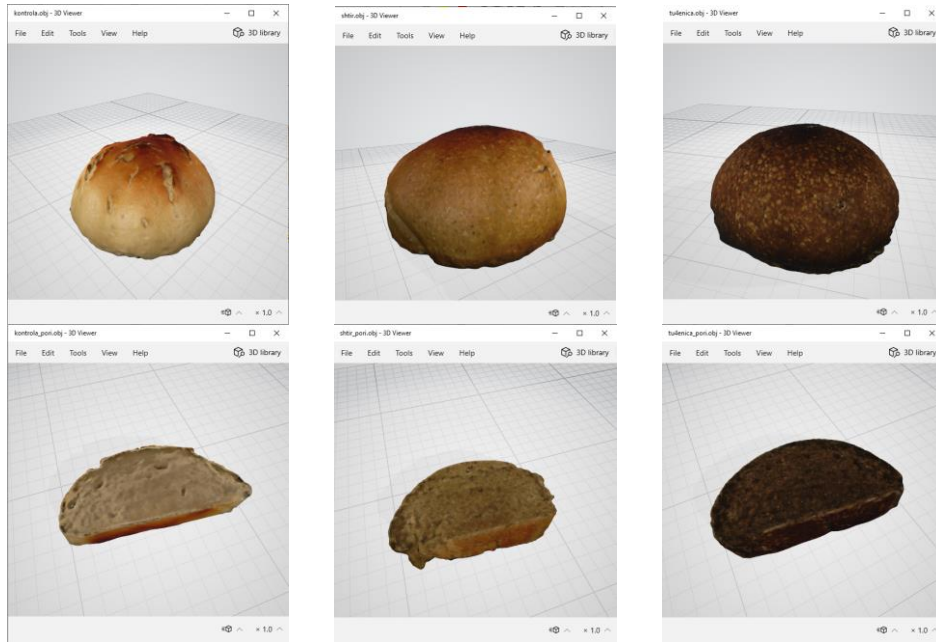
The resulting floor bread was scanned with a 3D scanner, model SOL CA73A (Scan Dimension, Allerød, Denmark), with a working rotary table. The scanning was done with the software SOL Creator Ver.22 (Scan Dimension, Allerød, Denmark).

The three-dimensional images of the object — bread — are stored in the .OBJ file format. Its conversion to .STL was done with the online tool ImageToSTL (ImageToStl, 2025).

In the STL file, a 3D object is represented as a series of connected triangles (Lee et al., 2019). Each triangle is defined by its three vertices and a normal vector. These triangles describe the surface of the object with a sufficiently high level of detail.

Figure 1 displays three-dimensional (3D) scanned images of bread samples made from the addition of pigweed and purslane flour. Each sample is represented in two perspectives: the whole loaf (top row) and cross-section of the crumb structure (bottom row). The images were captured with the bread placed upon a flat horizontal surface and visualized with imposed texture to facilitate close-up surface inspection. The products are placed in the middle of the frame and observed at a slightly slanted angle, having complete view of their structure and form.

For the control sample (a), the bread is uniform in color with pale golden brown color, smooth with fine texture, even crumb structured with porous and soft touch. Upon the addition of 3.7% pigweed flour (b), the bread is darker in color and has some roughness on the exterior, and the crumb also becomes denser in appearance with a firmer texture. The differences are most evident in the instance of 7.1% purslane flour sample (c), where the bread takes on a far darker color with the exterior possessing a rough, nonglossy surface. The texture of the crumbs appears coarser and more dense than in the remaining samples.



a) control sample

b) 3,7% pigweed

c) 7,1% purslane

Figure 1. Three-dimensional (3D) images of floor bread with the addition of pigweed and purslane flour

Table 2 presents an algorithm for processing STL files with 3D scanned floor bread. This algorithm works on an STL file by calculating its geometric and physical properties. First, the STL file is imported, and then the user specifies the mass of the object before the algorithm orients the object along its main axes using PCA (Principal Component Analysis). The volume and surface area of the object are then calculated using a function, and the density, which is the mass divided by the volume, is calculated. The algorithm calculates the dimensions of a bounding hemisphere — diameter, radius, and height — as well as the diffusion coefficient as the ratio of the height to the diameter. The results are in terms of volume, surface area, density, H/D ratio (height over diameter), and properties of the hemisphere. The object and the minimal hemisphere are plotted on a common 3D coordinate system.

To determine the main characteristics of a floor bread based on data from a *.STL file, available mathematical relationships were used.

The diameter of the loaf D , mm is determined by the following relationship:

$$D = x_{max} - x_{min} \quad (1)$$

where x_{max} and x_{min} are the maximum and minimum values along the x-axis of the 3D image of the loaf (the lower part of the loaf can be conditionally assumed to be a circle).

The height of the loaf H , mm is determined by the following relationship:

$$H = z_{max} - z_{min} \quad (2)$$

where z_{max} and z_{min} are the maximum and minimum values along the z -axis of the 3D image of the bread.

The spread factor SF (a dimensionless quantity) is determined by the following relationship:

$$SF = \frac{H}{D} \quad (3)$$

where H , mm is the height of the loaf; D , mm – its diameter.

The center of the minimum hemisphere is determined by:

$$C = \left(\frac{x_{min} + x_{max}}{2}, \frac{y_{min} + y_{max}}{2}, z_{min} \right) \quad (4)$$

where x , y and z are the coordinates of the object (bread) in the 3D image.

The volume V , mm^3 of the minimal hemisphere is determined by:

$$V = \frac{2}{3} \pi r^3 \quad (5)$$

where r , mm is the radius of the base ($r=D/2$).

Area A , mm^2 of the minimal hemisphere is determined by:

$$A = 2\pi r^2 \quad (6)$$

where r , mm is the radius of the base.

The surface area of the loaf and its volume are defined by the tetrahedra formed by the triangles and their vertices, by which the object is represented. Each triangular face in the STL mesh is treated as part of a tetrahedron, where one vertex is at the origin (0,0,0), and the other three vertices are the vertices of the triangle from the STL file.

The volume of the i th tetrahedron V_i , mm^3 is defined by:

$$V_i = \frac{1}{6} |v_0(v_1 \times v_2)| \quad (7)$$

where v_0 , v_1 and v_2 are the three vertices of the triangular face of the object (bread); \times is a cross multiplication, which results in a vector perpendicular to the triangle.

The total volume of the bread V , mm^3 is determined by:

$$V = \sum_{i=1}^N V_i \quad (8)$$

where N is the total number of triangular faces in the STL file.

The surface area of a tetrahedron A_i , mm^2 is defined by:

$$A_i = \frac{1}{2} \|(v_1 - v_0)(v_2 - v_0)\| \quad (9)$$

where v_0 , v_1 and v_2 are the three vertices of the triangular face of the object (bread).

The total surface area of the entire loaf is given by:

$$A = \sum_{i=1}^N A_i \quad (10)$$

where N is the total number of triangular faces in the STL file.

The PCA method was used to align the 3D object because the STL file contains 3D points without a predefined orientation. PCA finds the natural principal axes of the object and aligns it. This ensures that the diameter is correctly measured in the X-Y plane. The height is correctly measured along the Z axis. The object is in a standardized position for the following calculations.

The command `[coeff, ~, ~] = pca(vertices)` was used. `pca(vertices)` calculates the principal components of the vertex coordinates. `coeff` contains the eigenvectors of the vertex covariance matrix. These vectors define the two principal axes of the object.

The data is centered (the mean of each coordinate is subtracted). The covariance matrix C of the centered data is calculated:

$$C = \frac{1}{N} \sum_{i=1}^N (v_i - v_m)(v_i - v_m)^T \quad (11)$$

where v_i is the i^{th} vertex; v_m is the average over all vertices.

The eigenvectors and eigenvalues of C are calculated. The eigenvectors are obtained in the `coeff` matrix.

The rotation of the object using the principal components is obtained with the command `rotatedVertices = (vertices * coeff)`. The original coordinates of the vertices are transformed by multiplying them by the coefficient of the principal components matrix. This aligns the object so that its longest dimension lies along one of the principal coordinate axes. The new coordinate system makes it easier to analyze properties such as height, width, and depth.

The characteristics of the bread are calculated after it is oriented relative to the X-Y surface, as shown in Figure 2.

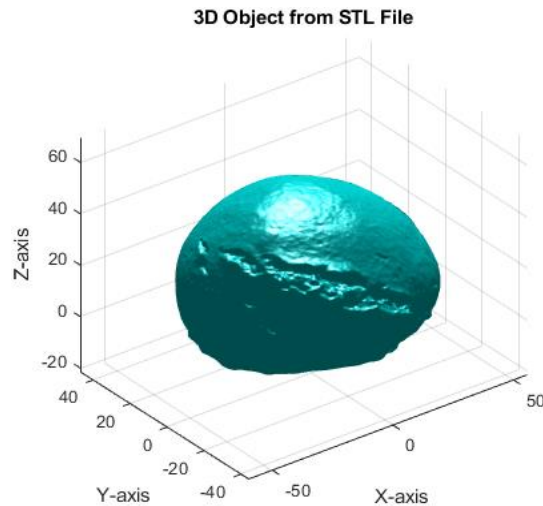


Figure 2. Bread position after alignment relative to the X-Y surface

Table 2. Algorithm for processing 3D images of bread

Stage	Step	Description
1	Input variables	STL file; Bread mass, g
2	Calculating the principal axes	Use PCA to determine the principal axes of the object
3	Calculating volume and surface area	Calculate the volume and surface area of the aligned object using the function (<i>stlVolume</i>).
4	Calculating density	Calculate the density of the object using the formula $Density=Mass/Volume$
5	Minimum hemisphere and geometric properties	Calculate the dimensions of the minimum hemisphere, diameter, radius and height of the object
6	Calculating the spreading factor	Calculate the spreading factor (H/D) as the ratio of height to diameter
7	Drawing a hemisphere	Overlay the original object with the minimum hemisphere and visualize on a 3D coordinate system
8	Output variables	Volume, surface area, density, spreading factor, hemisphere properties
9	STL volume function (<i>stlVolume</i>)	Function that calculates the volume and surface area of the STL object using its vertices and faces

The STL Volume Function (*stlVolume*) is presented in Table 3. The volume and surface area of a 3D object, which are calculated from the vertex and face data from the STL file. The volume and surface area variables are initialized, and then for each face of a triangle in the object, the algorithm extracts the vertices for each triangle, then calculates the volume of the tetrahedron forming that triangle and its surface area, summing them into a current total volume and surface area. At the end, an absolute value is calculated to ensure that the sign of the result is positive.

Table 3. Algorithm of STL Volume Function (*stlVolume*)

Stage	Step	Description
1	Input variables	Vertices and faces from STL file
2	Initialize volume and surface area	volume = 0; surfaceArea = 0
3	Traverse each triangular face	Extracting the vertices of a triangle
3.1	Calculate the volume of the tetrahedron	-
3.2	Calculate the area of the triangle	-
3.3	Add to volume and surfaceArea	-
3.4	Finally - take the absolute value of the volume	-
4	Output variables	Volume, Surface Area

Figure 3 illustrates three-dimensional (3D) images of bread enriched with pigweed and purslane flour, along with the minimal hemisphere outlined around each of them. Among the samples, the control has the largest volume and is quite uniform in surface and shape. Minimal deviations from the hemispherical shape and volume are observed for the sample with 3,7% pigweed content. The most significant difference occurred for the sample containing purslane flour (7,1%), which had the lowest volume and shape deviations compared to the other samples.

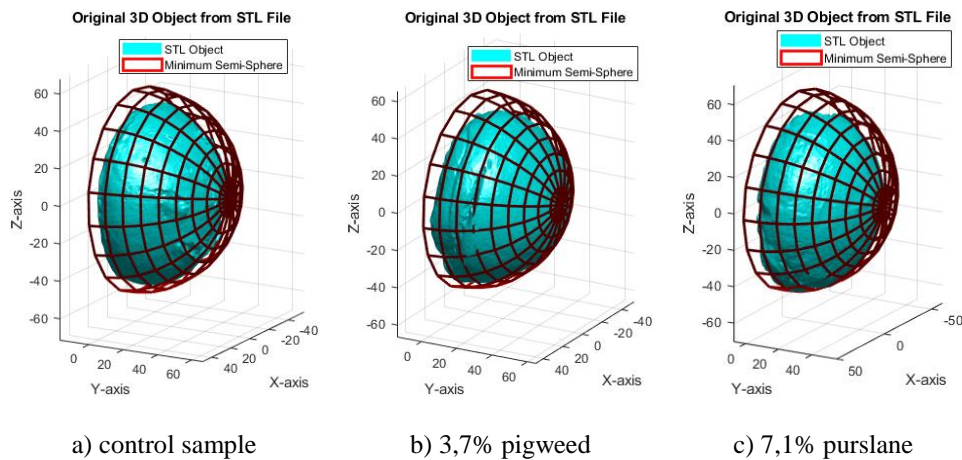


Figure 3. 3D images of a floor bread with a minimal semi-sphere circumscribed around it

Table 4 presents measurements of floor bread with additives. A comparative analysis was made of the three types of bread Control, Pigweed and Purslane in terms of volume, area, density, spread factor and measurements of the minimum hemisphere. Purslane bread has the largest volume and area compared to the other samples, while pigweed bread has the smallest values, especially for volume and area of the hemisphere. The density of all breads is similar, but Pigweed bread contains the highest spread factor, indicating greater spreadability of the dough.

Table 4. Bread measurements

Bread type Characteristic	Control (Mean \pm SD)	Pigweed (Mean \pm SD)	Purslane (Mean \pm SD)
V of bread, mm ³	211760.34 \pm 5000	209970.74 \pm 4800	219020.27 \pm 5200
A of bread, mm ²	20479.20 \pm 450	19386.53 \pm 430	20523.38 \pm 470
Density D, g/mm ²	0.00042 \pm 0.00001	0.00042 \pm 0.00001	0.00041 \pm 0.00001
Spread factor SF	0.52 \pm 0.02	0.56 \pm 0.02	0.50 \pm 0.02
V of semi-sphere, mm ³	315913.88 \pm 7000	266340.54 \pm 6500	323540.30 \pm 7200
A of semi-sphere, mm ²	17805 \pm 400	15889.09 \pm 350	18089.49 \pm 420

4. Discussion

The work related to 3D scanning of bread can significantly support and diversify the learning strategies of students. The visualization and analysis of bread with functional additives is an example of the application of modern technologies in education. The results obtained in this work complement those of Uyar & Erdogdu (2009), according to which the use of 3D scanning in food technology removes the complexity of traditional teaching methods and provides easily digestible modular elements. This is also emphasized by Minchev & Pizarova (2024), according to whom the integration of new technologies such as 3D scanning in geometric modeling training makes concepts more understandable for students. The authors of the material believe that the application of 3D scanning promotes student engagement and leads to deeper learning. Neminska (2023) points out that the interdisciplinary integration of new technologies such as 3D scanning helps students to connect scientific and practical applications. Lee et al. (2019) noted that visualizations obtained from 3D scanning stimulate interest in food science and increase digital literacy. In the case of bread, with functional additives, learners can visually assess and analyze changes in the texture and structure of the product, which improves their analytical approach. Future directions for the development of 3D scanning of bread are related to the integration of augmented reality (AR) and the creation of virtual platforms for food product analysis. Artec 3D (Artec Europe, 2025) suggests that the application of AR can provide new methods of visualization and interaction. Virtual platforms would allow learners to access resources remotely and experiment with different models and methods. Improving training resources, including the development of detailed manuals and training videos, would facilitate the understanding and application of 3D scanning in food technology (Creaform, 2025).

It can be summarized that:

- 3D scanning allows better visualization and analysis of bread with functional additives, which is better for learning and more interesting and interactive;

- The technology simplifies intricate food science concepts into something less complex and more applicable;
- Future advancements can even include augmented reality (AR) and virtual spaces to provide an enhanced food product discovery;
- Even more smooth training tools, such as textbooks and videos, can even help to make 3D scanning more adoptable in education for food technology.

5. Conclusion

This paper investigates and integrates 3D scanning technology in food technology education, applied to bread analysis. The application of 3D scanning to create realistic models and analyze the properties of bread with functional additives is analyzed.

3D scanning in scientific research is used to measure the quality indicators of bread with higher accuracy and higher reproducibility compared to traditional methods, customize packaging, and analyze structural changes in food products.

From a teaching perspective, 3D scanning offers the learner the opportunity to visualize abstract concepts, manipulate variables during scanning, and then analyze the result of these manipulations in an appropriate way.

Algorithms and procedures are adapted that are suitable for teaching 3D scanning technologies in food sciences.

The results of the study on 3D scanning of bread can be applied to improve pedagogical strategies and overcome didactic challenges in this field. Through effective integration of these technologies, learners can acquire in-depth knowledge and skills about the technical process of bread production and related scientific concepts, developing skills in data and results analysis, as well as forming critical thinking.

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Artificial Intelligence to support STEM learning in the classroom

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Abstract: *The implementation of artificial intelligence (AI) and the STEM approach in the classroom offers innovative solutions that turn learning into an interactive and transformative process. The authors of the article successfully implement projects that combine natural sciences and technologies in "Knyaz Alexander I" Elementary School, town Plovdiv. The article presents examples of good practices and the results of their implementation. In it, the authors examine applications to help the teacher (Diffit for Teachers, Magic School) and the student (Canva, Suno, D-iD, Slidesgo, Educaplay, Quizizz) related to the use of artificial intelligence. In an age of rapid technological innovation, education must meet the needs of the new digital generation of students. STEM education with the use of artificial intelligence enables students to be well prepared for the future, encouraging both creative thinking and social engagement.*

Keywords: STEM, artificial intelligence, teacher, student, learning.

1. Introduction

The use of educational software in the learning process is a modern and preferred means that increases student motivation and makes learning seamless and attractive. It is essential for the modern teacher to know the main characteristics of educational platforms and digital environments, the possibilities of their integration in the learning process, as well as in extracurricular activities, taking into account the age characteristics and the level of knowledge of the students. The use of artificial intelligence allows identification of the learning process, helps its differentiation and individualization.

Currently, AI is in its early stages of development as a mainstream technology, which means that each school can find its own approach and tools that suit the school's strategy and vision, integrate them extremely quickly into the learning process and increase the quality of the educational process (Mihailov & Mihailova 2023).

2. Exhibition

Students today demand dynamic educational approaches that match their learning styles and interests. Applications based on artificial intelligence are a key tool for motivating and engaging students. Implementing AI in the learning process enables personalized learning, quick access to resources and the ability to create interactive content.

At the heart of the change today are prompt generators, which enable a teacher to look beyond their most commonly used pedagogical model and give them some ready-made AI-powered solution where they can use an expert model of another type of teaching, such as we are convinced that if this thing is made so that teachers can easily and intuitively work with it in a web environment (Georgieva, 2024).

The authors of the article are professors of information technology. This gives them the opportunity to introduce students to innovative educational software (Velcheva, 2021), specialized electronic systems (Stoitsov & Aneva, 2014), simulation software (Stoitsov, 2017) and how to work with them (Steriu & Stănescu, 2023).

With this article, the authors want to prove that artificial intelligence applications for creating and conducting STEM training can be used in compulsory, optional classes and in extracurricular activities related to natural sciences and information technologies in junior high school.

The authors, as school and university educators, spent months exchanging ideas and sharing innovations related to the application of artificial intelligence in the classroom in a professional learning community of educators in various fields and experts. They managed to prepare and implement several successful STEM trainings in junior high school using artificial intelligence applications in March, April and June 2024 ("Water - the source of life", "Ideathon for children", "Healthy nutrition"). The increase in the number of students who get involved in each subsequent event with enthusiasm, the involvement of the school community and institutions, the magnitude of the training that goes into the events and causes are the factors that determine success. The authors of the article, on the basis of these results, are planning and forming a class in the 5th grade with an enhanced study of natural sciences and information technologies, and the use of artificial intelligence should be included in the curriculum. The academic year 2024/2025 in "Knyaz Alexander I" Elementary School started with a STEM class of 29 students. The author of the article conducts the mandatory classes in information technology and additional ones, as well as those in natural sciences. In order to increase the hours in which the children will be educated using artificial intelligence and the STEM approach, she also formed a club "Digital Virtuality" (extracurricular activity). Mentor of the students is the author of the article, in his capacity as a teacher at the

Faculty of Mathematics and Informatics.

The author of the article shares that she uses artificial intelligence applications to:

- lesson planning (Diffit for Teachers, Magic School);
- creating tests and games (Quizizz, Educaplay);
- creating presentations (Canva, Slidesgo, Complete);
- image generation (Canva);
- creating videos (D-ID);
- music generation (Suno).

2.1 Artificial Intelligence applications to help the teacher

Diffit for Teachers is a platform that uses artificial intelligence to adapt learning resources to the individual needs of students. The application is used to create educational materials that are tailored to the different levels of student preparation. The authors of the article share that they use the platform to generate lesson plans, texts, quizzes that can be adapted to be both challenging and understandable for each student.

Magic School is a particularly useful tool for primary school STEM initiatives. Teachers can organize project-based activities, with the platform offering ideas, resources and guides.

Magic School provides digital simulations and research tools that contribute to hands-on learning. The advantages of the application are related to saving time, increasing student engagement. The platform promotes the use of new technologies and pedagogical approaches in education.

With the help of these applications, educators can create more engaging, personalized and effective learning environments that meet the needs of today's students, the authors of the article share.

2.2 Artificial Intelligence applications to help the student

In the compulsory and optional classes on computer modeling and information technology, as well as in the classes for activities of interest, the author of the article says that she introduces students from the junior high school stage to interactive applications working with artificial intelligence.

Apps for creating tests and games (**Quizizz, Educaplay**)

Educational technology has long focused on engaging students through games and interactivity. Apps like Educaplay and Quizizz provide platforms that

not only facilitate learning but also make the learning process fun and engaging for the digital generation. At Prince Alexander I Primary School, these applications have been successfully integrated into STEM learning, contributing to improved engagement and understanding of learning content.

Educaplay is a platform for creating educational interactive resources such as quizzes, crosswords, puzzles, video tutorials and more. As part of the training, students from grades 5 to 7 actively participate in the development and solving of tasks created through this platform. Students have the opportunity to create their own quizzes and games, encouraging them to explore the topic in depth and demonstrate critical thinking.

The results of using the application are related to the promotion of active learning through gamification.

Quizizz is an innovative platform for creating interactive tests and quizzes that take place in real time or one-on-one at a time convenient for students. The main advantages of the platform for junior high school students include:

- Motivation through competitive element;
- Custom tests with II;
- Analysis of results.

Teachers can use Quizizz's functionality to analyze answers in real time, which allows identifying gaps in knowledge and adapting the learning process, the authors of the article share.

Educaplay and Quizizz are powerful tools that integrate game elements and artificial intelligence technologies to meet the needs of the new generation of learners. These apps change the dynamics of the classroom, combining fun and learning, and are a testament to the successful transformation of traditional pedagogical approaches. Their use in STEM education creates a foundation for active and engaged learning, preparing students for the challenges of the future.

Apps for creating presentations (**Canva, Slidesgo, Gama**)

Canva is a powerful visual design tool that offers integration of AI technologies making it easy to create professional looking graphics. Students use Canva to design posters, badges, brochures and t-shirts. Thanks to built-in AI features such as automatic design generation, color coordination and font suggestions, they achieve high results with minimal effort. Environmental projects stimulate students to express their ideas in a creative way, while developing their visual culture and critical thinking.

Slidesgo is a platform that provides professionally designed presentation templates compatible with Google Slides and Microsoft PowerPoint. The application is extremely useful for teachers who want to present the learning material in an attractive and visually organized way suitable for the digital

generation of students.

In environmental initiatives such as Ideathon for Kids (featured further down in the article), teachers and students use the platform to create visuals that support campaigns or present solutions to environmental issues.

Slidesgo is a useful tool for bringing together data, visualizations and ideas created through other applications such as Canva, Diffit and Suno. For example, students can include diagrams generated with AI tools or images created with Canva into presentations based on a Slidesgo template, the paper's authors say.

Complete is an innovative tool that helps students create interactive presentations, data visualizations, and simulations. The platform was built with modern education in mind, emphasizing STEM (Science, Technology, Engineering and Math) and encouraging students to immerse themselves in inquiry and creative problem solving.

Music and video creation apps (**Suno, D-ID**)

Suno is a text authoring application that uses artificial intelligence to generate content such as poetry, essays, and descriptions. During the lessons, the 7th grade students write poems on an environmental theme, with Suno offering ideas, structures and lexical suggestions. This facilitates the writing process and makes literary creation accessible to all students, regardless of their experience.

D-ID is an innovative application that uses artificial intelligence to create text-based video content with talking avatars. This offers unique opportunities for students, enriching the learning process and encouraging the development of communication skills, creativity and technological literacy.

Students can create their own video projects by turning text material into talking avatars. This motivates them to express ideas in an interactive and visually appealing way.

Creating videos is suitable for presenting projects, telling stories or sharing research, the authors say.

D-ID and Suno provide good opportunities for students to express themselves in an innovative way, develop their digital and communication skills and learn with interest. The integration of apps in the classroom makes learning more accessible, interactive and relevant to the needs of today's generation.

2.3 Shared practice

One of the key initiatives is the "**Ideathon for Kids**", conducted within the framework of the COMPAIR project by the authors of the article. The project includes a series of activities aimed at measuring air quality and promoting a sustainable lifestyle. Participants (5th, 6th and 7th grade students) prepare projects in five categories (Figura 1):

- Video contest - short videos on the topic "Protection of the environment". To create them, the students used Canva, D-iD applications and managed to achieve interaction;
- Presentations - presentations on air cleanliness. The presentations were created by sixth and seventh graders using Slidesgo and Canva;
- Eco-exhibition - 3D models and drawings related to Earth Day. Ideas were generated by Canva, Magic School, Diffit for Teacher;
- Literary work - essays and poems on the topic "The Earth - My Home";
- Advertising campaign - creating games, quizzes, tests, posters and news about nature conservation (Canva, Quizizz, Educaplay).



Figure 1. Poster

The STEM training on the theme "Ideathon for Kids" lasted for a month and included preparing students and creating resources in compulsory classes, in elective classes and in interest clubs related to science and information technology.

The event took place over 3 consecutive days, including the presentation of the projects in 3 halls, filming with a drone and camera, participation of 10 classes of students, representatives of institutions, parents and teachers. It ends with an official ceremony where students present their projects to parents, teachers and representatives of the Energy Agency – Plovdiv (Figure 2).



Figure 2. Poster

The Ideathon succeeded in uniting the efforts of students, parents and the school administration, turning the school into a model for transdisciplinary learning.

This event was the largest of the 3 organized events during the academic year 2023/2024, the authors share. It is this that leads to the idea of STEM - a class in 5th grade.

From October 2024 until January 2025 the authors conduct 3 more such trainings in the specialized class - "**Experimenters**", "**Young programmers**", "**Graphic editors**".

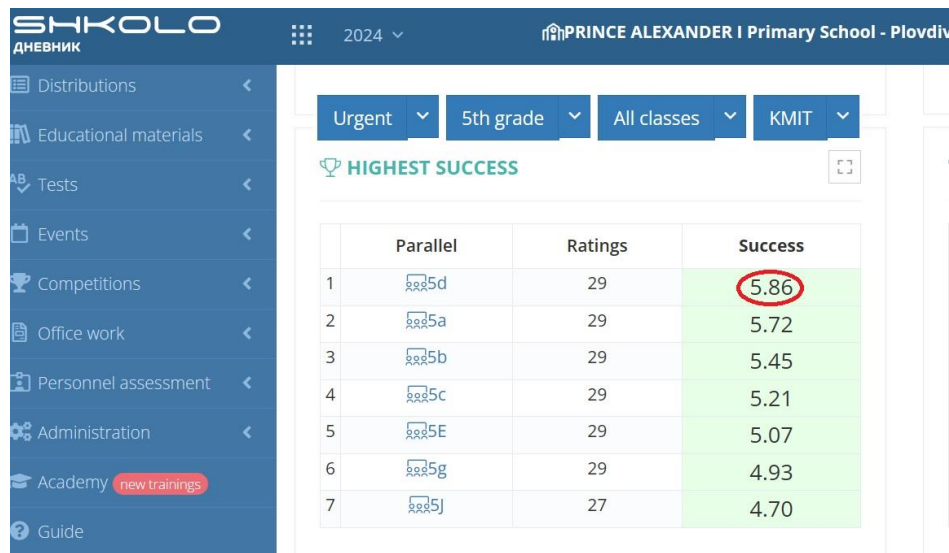
Students plan the initiatives together, thereby acquiring skills for effective time management, constructive teamwork, and determining their own opportunities. Placed in a problematic situation, they learn to defend their positions, acquire a willingness to compromise, build communication skills in different environments. During all events, celebrations, competitions, causes, the students of the club conduct negotiations, set goals and manage to achieve them. They get inspired and personally commit to the causes.

The authors of the article believe that the use of artificial intelligence in the classroom offers an opportunity to expand the student's interests, develop abilities, discover new interests, develop and improve aptitudes and talents. This is the basis for acquiring personal and social competence (Borisova, Hadzhikoleva, Hadzhikolev & Gorgorova, 2023).

The knowledge, facts and skills that students acquire when using artificial intelligence applications are the foundation needed to create their own digital content through critical thinking and analysis. By using interactive applications related to artificial intelligence and the STEM approach, students acquire teamwork skills, develop their critical thinking, apply their knowledge in real life, in short, go beyond the boundaries of the classroom and prepare for real life. discover their strengths and guide themselves in choosing a profession.

2.4 Learning outcomes

At the end of the 1st term, the STEM class has the highest average success in information technology (mandatory study hours) of all 7 classes in the 5th grade (Figure 3).



	Parallel	Ratings	Success
1	5d	29	5.86
2	5a	29	5.72
3	5b	29	5.45
4	5c	29	5.21
5	5e	29	5.07
6	5g	29	4.93
7	5j	27	4.70

Figure 3. Success

Completed 3 STEM trainings ("Experimenters", "Young programmers", "Graphic editors") with an excellent result in additional classes in natural sciences and information technology (Figure 4).



Figure 4. Shared practice

In the "Digital Reality" club, all the planned events were carried out, and not only students, but also parents and teachers participated enthusiastically in them.

3. Conclusion

The use of artificial intelligence in STEM education is changing traditional educational methods, providing students with opportunities for creativity and innovation. In "Knyaz Alexander I" Primary School, these technologies improve the quality of education. With the introduction and use of artificial intelligence in the educational process, according to the authors of the article, the teacher becomes an innovator who makes the connection between formal and informal learning, connects theory with practice, activates creativity in his students, who have the skills and competencies to work with current technologies. This leads to a modern education that meets the needs of today's digital generation and defines the place of artificial intelligence and STEM education in the educational process.

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A security model with biometric components for e-learning systems

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Abstract: *The paper presents an innovative security architecture with multimodal biometrics for e-Learning systems. The biometric data fusion is approached using a hierarchical methodology for feature-level fusion with 2 layers, local (intra-modal) and global (inter-modal) fusion. Some design options are proposed to be explored and evaluated in order to establish their feasibility for e-Learning platforms. This proposal belongs to an ongoing research with focus on improving the security in applications from various areas and in which the multimodal biometrics should be used.*

Keywords: biometric, multimodal, e-Learning.

1. Introduction

The e-Learning platforms and systems are evolving very fast, significantly changing the educational systems. Through the integration of the most advanced technologies and innovative teaching strategies, this educational framework provides sustainable and effective solutions to contemporary training challenges. The expansion of technological platforms for distance learning and e-Learning requires the integration of effective security mechanisms. The design of security mechanisms for e-Learning should consider the optimization in respect to the technical requirements of those applications, but ensuring a proper level of security and reliability. These requirements are enabled by the actual trend to enlarge the spectrum of cybersecurity threats against the hardware/software platforms for a wide variety of applications.

The biometric technologies provide a reliable approach to develop efficient authentication mechanisms that can be integrated into multi-factor schemes. The advances in biometric systems, either for desktop but also for mobile use-cases, are key factors enabling to improve their integration in applications for many domains, including e-Learning.

The paper proposes a security model for e-Learning platforms. The architectural model addresses the problem of the secure user authentication; it includes multimodal biometric components. The design specifies the client-side

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and server-side components. The biometric data fusion is approached with a hierarchical methodology for feature-level fusion with 2 layers, local (intra-modal) and global (inter-modal) fusion. Some design options are proposed to be explored and evaluated to further establish their feasibility for e-Learning platforms. This proposal belongs to an ongoing research with focus on improving the security in various applications and in which the multimodal biometrics should be used. The remainder of the paper is structured as follows: Section 2 - recent related works; Section 3 - the proposed security architectural model, and potential future improvements; Section 4 that concludes this work, with steps towards a software implementation.

2. Related works and current developments

Given the technological advances, the adoption of e-Learning systems and platforms significantly increased, becoming an essential component of the educational landscape. e-Learning is highly adaptable and accessible, providing an efficient modality for various learning activities (Zogas et al., 2016).

According to (Al-Fraihat et al., 2020), e-Learning offers fast and personalized learning strategies with high efficiency in the educational process. An important challenge for the online learning is the quality assurance (Gheorghe-Moisii & Tîrziu, 2015) and integrity of the online educational processes.

The biometric technologies provide a reliable way to validate the student identity and to prevent the security breaches in the online education. The use of fingerprints and other biometrics has proven to be reliable in strengthening the educational processes security (Ivanova et al, 2019). A biometric system extracts and matches features of the human body such as fingerprint, iris, and face to identify individuals (Soviany et al., 2023).

The state of the art in the biometrics' usage for the individual's authentication in online learning environments is presented in (Curran & Curran, 2021), followed by a detailed investigation of the authentication systems with face and iris for the learner authentication. The user authentication is a key factor for the e-Learning systems security. In (Luu, Nguyen, Pham, & Huynh-Tuong, 2020) a brief description of the authentication methods for online systems was made: ID/password, biometrics and the user behaviour. Shen et al. proposed a real-presence detection system called IriTrack, which relies on iris tracking to prevent facial spoofing attacks. By asking users to move their eyes according to a randomly generated trajectory, the system analyses iris movements as evidence of real presence (Shen et al., 2018). Afolabi & Adagunodo described a secure multimedia e-Learning system based on facial recognition and data encryption; the implementation of the system was carried out in three main stages (Afolabi & Adagunodo, 2018): a) Facial recognition, b) Data encryption, c) Implementing the multimedia-focused e-learning.

The multi-biometric systems have been developed as reliable solutions for authentication. Many researchers have proved their effectiveness, showing that in multi-biometric (multimodal) systems, the various biometric traits can overcome the limitations of the single-modal systems. Although the biometrics can be combined at different levels (feature, score, or decision), the matching score-level fusion is commonly applied because of its low complexity. Herbadji et al. propose a multi-biometric system based on the fusion of 2 different techniques: triangular norms and rule-based classifiers such as SVM (Support Vector Machine) (Herbadji et al., 2020). (Daza et al., 2022) present edBB-Demo - a research platform that integrates biometric authentication and behavioural analytics for the student monitoring in the distance education. The feature fusion remains a hot topic because of its major challenges: the curse-of-dimensionality (if the features are concatenated); the issue of finding relationships among the original feature spaces, together with the potential incompatibility among the feature sets generated by different feature extractors (Jain, 2005); the unavailability of the feature vector structure to prevent potential security breaches. The feature-level fusion can be applied on several feature sets either extracted from the same biometric (intra-modal fusion, like textural and structural features extracted from the same input face image) or from different human traits or modalities (inter-modal fusion) (Singh et al, 2019).

The feature fusion has promising usage cases such as indexing and retrieval of biometric data allowing to develop computationally efficient, accurate, and privacy-preserving data storage and retrieval tools (Drozdowski, 2021). This is why there are ongoing research efforts to develop innovative feature fusion methods, basically looking to overcome the main drawback of the concatenation. The feature-level fusion can be addressed with techniques like clustering and indexing (Sasikala, 2018). Some simple fusion techniques like the weighted sum are applied for different use-cases (Atenco, 2023). The concatenation-based fusion is typically used with normalized features (Harakannanavar, 2022). More complex feature-level fusion methods include procedures like the Canonical Correlation Analysis (CCA) with a SVM classifier to get a highly discriminant fused feature vector (Kamlaskar, 2022); in this case a procedure with Principal Component Analysis (PCA) + CCA subspace is applied to achieve a reliable dimensionality reduction within the feature fusion framework.

3. The security architectural model with multimodal biometrics for an e-Learning platform

3.1 Basic architecture (model)

The security architecture for the e-Learning use-cases is depicted in Figure 1. It includes a multimodal biometric authentication component to be used by the e-Learning platform end-users. The client-side component includes the biometric data processing together with the data fusion. The data processing module performs

the feature generation. The server-side component includes the matcher (data classifier) within an access control module; the matching process is applied to a Key Generator allowing that individual to have access to the e-Learning platform functionalities. The design specifies: the feature generation, the data fusion, the biometric data classifier and some improvement/optimization options.

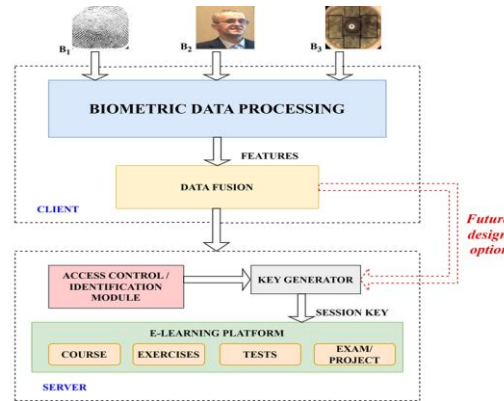


Figure 1. Security Architecture for e-Learning

3.2 Feature generation/extraction process

The feature generation process (Figure 2) is based on a regional approach in which several regions of interest (ROIs) are manually selected and extracted from the original images to get the informative features. The 3 biometrics are fingerprint (B_1), face (B_2) and iris (B_3). The main steps are as follows:

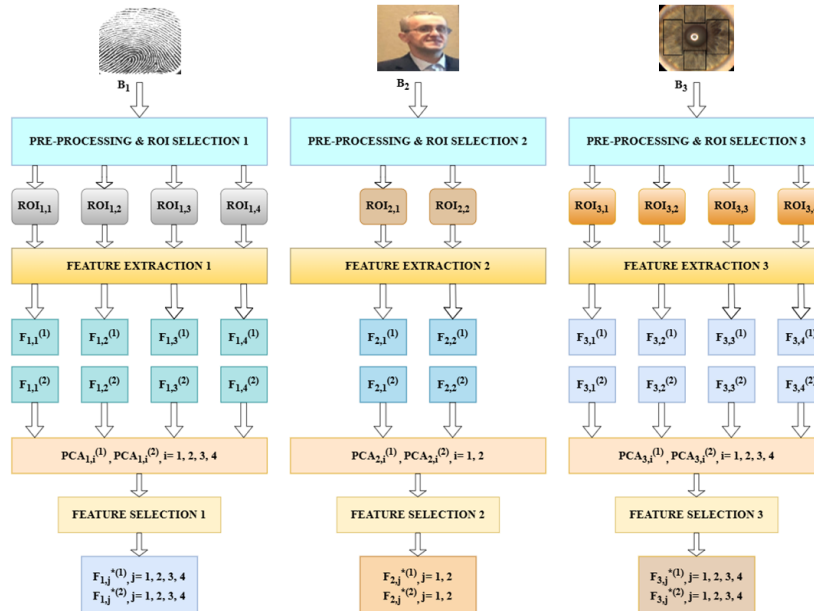


Figure 2. Feature Generation (client-side)

The pre-processing and ROI selection/extraction, in which the original images are pre-processed to enhance their quality. The pre-processing step will perform operations like image clipping, noise removing and thresholding. The main operation is the manual selection and extraction of a specified number of ROIs from every pre-processed image. The ROIs will be used for the feature generation (feature extraction, dimensionality reduction, optionally Feature Engineering and feature selection). For the specified biometrics the number of ROIs is as follows: $n_{ROI_{B_1}} = 4$, $n_{ROI_{B_2}} = 2$ and $n_{ROI_{B_3}} = 4$;

The feature extraction from the selected ROI, using an approach with textural features (Haralick). The same Feature Extractor model is applied for all biometrics: regional process with several ROIs, textural 1st and 2nd order statistical features. The extracted features evaluate the gray-level distribution within the selected ROI: per pixel (1st order statistical features) and per pair of neighboring pixels with a certain displacement (2nd order statistical features). The co-occurrence matrices are used to derive 2nd order statistical features (Theodoridis, 2009), (Lofstedt, 2019), (Mansour, 2023). The feature extractor uses as the main parameter the number of gray-level bins (GLB). For each selected ROI from the original image there will be 2 feature vectors containing the 1st and 2nd order textural features. The 1st order features include the mean value of GL (gray-levels) and the central moments: variance, skewness and kurtosis. These amounts are evaluated based on the 1st order histogram - the ratio between the number of pixels with the given GL and the total number of pixels within the selected ROI, and for a certain number of possible gray-levels. The resulting feature vectors are $F_{B_k,j}^{(1)}, B_k \in \{B_1, B_2, B_3\}, j = \overline{1, n_{ROI_{B_k}}}$. The 2nd order statistical features are based on the co-occurrence matrix (CM) with elements computed as the ratio between the number of pixels with a certain displacement between them having the specified gray-levels and the total number of possible pairs (Theodoridis, 2009). The total number of CM elements is $(GLB)^2$. The CM-based feature extractor parameters are fixed to maximize the number of non-null (informative) CM elements. The 1st parameter (GLB) ensures a proper adjustment of the feature space size in respect to the performance vs. complexity trade-off. The 2nd parameter (offset) is used to adjust the spacing between the pixels pairs. After the CM generation, additional variables are computed based on the CM elements: Angular Second Moment (ASM), Contrast (CON), Inverse Difference moment (IDF), Entropy, Correlation (Mansour, 2023), Autocorrelation, Dissimilarity (Lofstedt, 2019), Variance. These texture features are concatenated to the vector containing the CM elements. The resulting feature vectors are $F_{B_k,j}^{(2)}, B_k \in \{B_1, B_2, B_3\}, j = \overline{1, n_{ROI_{B_k}}}$;

The dimensionality adjustment through PCA. PCA (unsupervised process) retains the features having the highest variance and the lowest correlation but with the potential drawback of not preserving the class separation among the samples within the datapoints space. A supervised PCA version could be a design option to

improve the process, for example by using a weighted covariance matrix. The weighted covariance matrix could be computed based on the class covariance matrices while taking as weights the priors (occurrence frequencies) of the classes (target and non-target identities) within the training biometric data;

The feature selection and Feature Engineering (FE) (optionally). The feature design/generation process for the biometric recognition of the e-Learning platform users could include a feature selection stage looking to search for and to retain the most useful features to be applied in the advanced data processing (data fusion in the client-side and data matching/classification in the server-side). For the feature selection one can apply typical techniques that are already known for pattern recognition use-cases (Theodoridis, 2009), but avoiding those methods evaluating the discriminant power per individual feature. For the feature generation step one can take in account the almost inherent correlation among the different features. Suboptimal searching techniques are considered for the feature selection: sequential forward selection. The feature selection ensures a common dimensionality for the vectors containing the same order textural features from different ROIs and for the same biometric. This ensures the homogeneity required for the functional feature fusion (intra-modal fusion). An optional process should be to derive new features from the original ones through FE. FE allows to enrich the initial feature space with new variables ensuring potentially higher discriminant value. This process assumes the cost of a certain dimensionality increasing. The improved feature space may reveal hidden data patterns that cannot be observed within the original space. The following FE techniques are considered (Heaton, 2016):

- counts, in which the new features are computed by fixing a certain thresholding and counting the cases where the specified original features exceed or are below the given threshold. One can take the number of non-null CM elements, or can specify a certain interval for the textural features values;
- differences and ratios, in which the new features are engineered by taking the differences and ratios between the maximum and minimum values of the given original features.

The resulted dimensionality (feature space size) for the 2 feature sets per ROI and per biometric is $d_{B_k,j}^{*(z)}$, $j=1, n_{ROI_{B_k}}$, $B_k \in \{B_1, B_2, B_3\}$, $z \in \{1, 2\}$.

3.3 Biometric data fusion scheme design

The biometric data fusion process is addressed with a pre-classification (feature-level) fusion methodology. The reason is the capability to exploit the informative properties of the raw samples, before any advanced processing that could generate a certain loss of information, as in the post-classification fusion – score-level, ranking-level, decision-level. The proposed feature-level biometric data fusion methodology uses a hierarchical approach with 2 layers, local and

global. This is justified by the regional approach of the feature extraction with several ROIs per biometric providing the corresponding feature sets to be fused. The 2 fusion layers are as follows:

The local biometric feature-level fusion is the process in which the extracted features per ROI are combined for every biometric (an *intra-modal* fusion). The local fusion is performed such as the 1st order textural statistical features provided by the all ROIs for the same biometric ($F_{B_k,j}^{*(1)}$) are combined with a functional rule f (1), and the same proceeding for the 2nd order statistical features ($F_{B_k,j}^{*(2)}$) (2). The 2 fused feature sets ($F_{B_k}^{*(1)}$), ($F_{B_k}^{*(2)}$) are then concatenated (3) to achieve the final feature vector for each biometric ($F_{B_k}^*$), where $B_k \in \{B_1, B_2, B_3\}$, and $n_{ROI_{B_k}}$ is the number of ROIs specified to extract the features from the input images, per biometric.

$$F_{B_k}^{*(1)} = f\left(F_{B_k,j}^{*(1)}\right), j = \overline{1, n_{ROI_{B_k}}} \quad (1)$$

$$F_{B_k}^{*(2)} = f\left(F_{B_k,j}^{*(2)}\right), j = \overline{1, n_{ROI_{B_k}}} \quad (2)$$

$$F_{B_k}^* = \begin{bmatrix} F_{B_k}^{*(1)} \\ F_{B_k}^{*(2)} \end{bmatrix} \quad (3)$$

The functional fusion requires homogeneous input feature vectors. A certain compatibility among the fused feature sets is ensured by using the same basic feature extractor for each biometric. The compatibility is another requirement for a reliable functional fusion. In this way the concatenation can be avoid for the fusion of the same order statistical features originating from the selected ROI. The concatenation is only applied to combine the 1st and 2nd order feature sets, according to (3), with a resulted feature space dimensionality

$$d_{B_k}^* = d_{B_k}^{*(1)} + d_{B_k}^{*(2)}, B_k \in \{B_1, B_2, B_3\} \quad (4)$$

The following methods are considered for the functional feature fusion scheme:

1. *Weighted Average (Sum) Fusion* (Chen et al., 2021), given by

$$F_{B_k}^{*(1)} = \sum_{j=1}^{n_{ROI_{B_k}}} w_j \cdot F_{B_k,j}^{*(1)} \quad (5)$$

$$F_{B_k}^{*(2)} = \sum_{j=1}^{n_{ROI_{B_k}}} w_j \cdot F_{B_k,j}^{*(2)} \quad (6)$$

where the weights w_j are normalized such as $\sum_{j=1}^{n_{ROI_{B_k}}} w_j = 1$. The weighting is done

based on the recognition performance per ROI. During the development process, the recognition performance will be separately evaluated with features sets extracted per ROI, before the data fusion. The performance will be evaluated using TPR (True Positive Rate) and FPR (False Positive Rate) on the target class (the identity to be recognized). Actually the weighting for the fusion rules is applied for all features per set. A modified version of the rule should assign weights per individual features according to their discriminant power, but with the cost of an increased complexity. The equations are quite similar, excepting the assigned weights per feature.

2. *Weighted Fusion for normalized features*, in which a weighted sum is applied on normalized 1st and 2nd order statistic textural features (Haralick). The defining equations for the local fusion rules remain quite similar to the previous case, but their application concerns the transformed features based on a sigmoid function (for both 1st and 2nd order feature vectors per ROI). The features to be fused can be normalized with the sigmoid function having as parameters the scaling and translation factors α , β like in (Han, 2020):

$$f(x) = \frac{1}{1 + \exp(-\alpha \cdot (x - \beta))} \quad (7)$$

in which the input variable x is an individual feature as extracted from the selected ROIs within the original images with the local feature space size $d_{B_{k,j}}^{*(z)}$, $x = F_{B_{k,j}}^{*(z)}[i]$, $z \in \{1, 2\}$, $j = \overline{1, n_{ROI_{B_k}}}$, $i = \overline{1, d_{B_{k,j}}^{*(z)}}$. The parameters should be fixed based on experimental data or using an empirical approach. A particular case of this function (with parameters the mean m_x and standard deviation σ_x of the input variable) is

$$f(x) = \frac{1}{1 + \exp\left(-\frac{(x - m_x)}{\sigma_x}\right)} \quad (8)$$

One can consider a double sigmoid function quite similar to one specified in (Jain, 2005) by:

$$f(x) = \begin{cases} \frac{1}{1 + \lambda \cdot \exp\left(-\alpha \cdot \frac{(x - \theta)}{\gamma_1}\right)}, & x < \theta \\ \frac{1}{1 + \lambda \cdot \exp\left(-\alpha \cdot \frac{(x - \theta)}{\gamma_2}\right)}, & x > \theta \end{cases} \quad (9)$$

where: the amounts λ and α are the shape parameters of the sigmoid function (that

should be provided based on the available data); θ is a threshold that is selected such as to fall into the overlapping region between the distributions of the scores for the target vs. non-target classes (enrolled identities for the biometric recognition); γ_1 and γ_2 are the boundaries of the region in which the sigmoid function behavior is almost linear. The last 2 amounts are selected such as to ensure an equal extension of the 2 distributions towards the left and the right around the threshold.

The global biometric feature-level fusion is the process in which the features from each biometric modality are combined into a single feature vector (an *inter-modal* fusion). The global fusion scheme concatenates the feature vectors previously resulted from the local fusion (10).

$$F = \begin{bmatrix} F_{B_1}^* \\ F_{B_2}^* \\ F_{B_3}^* \end{bmatrix} \quad (10)$$

3.4 Biometric data classifier design

The classifier design addresses the identification task. The classification with a Machine Learning (ML) model follows a multi-class approach in which each of the enrolled identities represents a class. The identification is a process in which the subject only provides his/her biometric credential and the system just guess his/her true identity without any username. The identification needs to explore a large searching space of the possible identities, therefore a multi-class design is required. For this design a conventional ML modeling is specified. Currently methods based on Deep Learning and particularly Convolutional Neural Network are used in many cases requiring image classification with advantages for feature representation and data classification. This research is still looking to explore the performance of conventional ML models (like SVM) on various biometric datasets, especially while making certain improvements of the original data space with FE techniques.

For the basic model one take the SVM classifier with a polynomial kernel (that is frequently used in image processing). The size of the training set will be fixed according to the condition specified in (Theodoridis, 2009), looking to ensure the best trade-off training set size (N_{tr}) vs. feature space size (N_{feat}) such as to prevent or to minimize the peaking and curse-of-dimensionality: $2 \leq \frac{N_{tr}}{N_{feat}} \leq 10$, where:

$$N_{feat} = d_{F_{B_1}^*} + d_{F_{B_2}^*} + d_{F_{B_3}^*} \quad (11)$$

$$d_{F_{B_k}^*} = d_{B_k}^*, B_k \in \{B_1, B_2, B_3\} \quad (12)$$

SVM is a binary classifier by default, therefore to properly manage the

identification as a multi-class problem one should apply a multi-class extension. For this design, the model is trained as a detector for a single target class (the enrolled identity) and the process will design several classifiers, one per identity.

3.5 Server-side: authentication and access control

The server-side component of the security architecture is depicted in Figure 3. This component includes the biometric matcher that basically performs the identification (biometric recognition) of the person providing the testing samples without any username. The biometric recognition output could be an ID (class membership) or a normalized score, depending on the design option for the classifier.

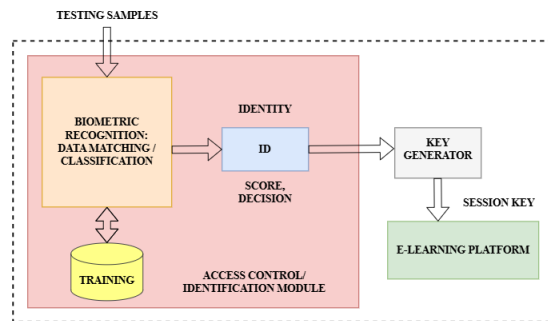


Figure 3. Feature Generation (server-side)

The key could be generated either based on the results of the biometric data matching but also one can take in account to directly use the fused features for this step. For example, one can consider methods like one presented in (Wang, 2021).

3.6 Various design options to be evaluated

Several design options will be further explored to develop a reliable and optimal security solution for e-Learning platforms:

- for the client-side components: feature selection and/or FE before or after feature-level fusion, an improved supervised PCA;
- for the server-side components: the mechanism for the key generation (based on the matcher outputs or on the fused feature);
- for the mobile devices (Android): the feature fusion could be applied between face and iris, as the developer cannot have full access to the fingerprint feature vector.

4. Conclusions

The current advances in algorithms, hardware, software and communications enabled a significant evolution towards the adoption of e-Learning. However, the security still remains a major challenge for many existing e-Learning platforms.

This justifies the efforts to develop and integrate advanced solutions able to enhance the security degree but also to meet the applications constraints (resources, complexity, costs, performance).

In this paper a security model for e-Learning was proposed, based on a multimodal biometric approach with feature fusion. In this ongoing research several data fusion methods are explored. The proposed security model addresses the problem of biometric identification, looking to design a reliable system able to accurately guess the true identity of the e-Learning platform users. The steps towards a software implementation include: the enhancement of the model with optimized fusion rules and several FE methods, the implementation of the client-side components with the functionalities for feature generation, the implementation of the server-side component including the key generator (based on the identification output or on the fused features), the integration of the developed modules. For the experimental tasks, the recognition algorithms (based on ML) will be tested using Python libraries like scikit-learn. The performances ensured by the proposed data fusion method will be evaluated measuring the execution time on several datasets.

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Section 2

Innovation and Best Practices in Virtual Education

3D printing in education – a way to foster learners’ activity and improve their creativity and design skills

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Abstract: *3D printing is one of the new technologies increasingly involved in training at different stages - from schools to universities. Although devices and supplies are still quite expensive and not all educational institutions can afford them, the benefits of their application have been proven over the recent years. Many authors present their experience and describe the possibilities for active learning by creating 3D models of complex systems, anatomical body parts, and machine parts that make learners go deeper into acquiring mathematical concepts. 3D printing in training engages learners and improves their practical skills; they become creators, not just passive information consumers. Even when learning is online, it is possible to set collective tasks for the preparation of 3D models, and then they will be combined and implemented by the teacher. These models can be used as a teaching tool in various disciplines and can also be sold. This improves learners’ teamwork skills and develops their communication and entrepreneurial abilities. The main purpose of this paper is to provide an overview of 3D technology, its areas of application, and the benefits of its successful application in education so that new digital learners are prepared for the challenges of tomorrow.*

Keywords: 3D printing, Education, 3D models, Active learning.

1. Introduction

Undoubtedly, 3D printing is one of the technologies that are becoming more and more popular and applicable in various fields - from creating small figurines and toys just for fun, to large 3D designs of buildings, anatomical organs and implants in medicine, in engineering to create spare car parts, and even in culinary to print shapes from food on the plate (Anandharamakrishnan, et al., 2022). To prepare people who can work with 3D printers, create 3D models, and know how to apply this technology, it is necessary to introduce it at each level of training.

The new generation of learners is digitally literate, different devices surround them, and each new technology provokes their curiosity and interest, making them more active and creative. Many STEAM (science, technology, engineering, arts, and mathematics) centers are equipped with 3D printers and through 3D printing, cross-curricular connections are made between different sciences, models of anatomical parts are created, models that reveal the structure of

atoms, chemical bonding, models of geographical and historical objects, etc. 3D printing is becoming increasingly accessible, even for personal use at home. There are free and easy-to-use software and platforms with available 3D models that users can download and use for free or at a low price.

To reveal this technology's potential for successful implementation in education, it is necessary to consider its essential functionalities, how it works, the types of 3D printers, and the materials used.

The main purpose of this paper is to provide a short overview of 3D technology, its areas of application, and the benefits of its successful application in education so that the new digital learners are prepared for the challenges of tomorrow.

Some of the research questions are identified as follows:

- What are the main functionalities and capabilities of 3D printing technology?
- What is the potential of implementing 3D printing in education?
- What are the challenges and benefits of integrating 3D printing in education?
- What pedagogical approaches could be used when adopting 3D printing in education?
- What are the future research areas in 3D printing research in education?

1.1 3D printing technologies

Historically, 3D printing has existed since the 1980s, but its popularity and use began two decades later. It is known as additive printing because the object is built up layer by layer from specific material (polymer, metal, and ceramic). It differs from the so-called subtractive-based ones, in which material is removed, such as grinding or milling (Schneider & Kumar, 2020) or under the influence of various factors such as temperature, pressure, etc. (Saptarshi & Zhou, 2019)

Regardless of the technology used, printing a 3D model goes through several stages (Figure 1). It starts with conceptualization, i.e., determining the part to be printed.



Figure 1. Stages of 3D printing technology

A 3D design is created and exported using specialized software to a Stereolithographic (.STL) file format. It is also possible to download a ready-made

3D model from platforms offering rich collections. To print the model, it is necessary to transform this file into a set of commands (GCode) that the 3D printer can understand and execute. The model is divided into layers by special software called a "slicer," usually built into most 3D printers. This software is suitable and can be used for almost all FDM printers. (Tully & Meloni, 2020)

Different 3D technologies depend on how the 3D objects are built: Fused Deposition Modeling (FDM), Poly Jet model, Selective Laser Sintering (SLS), Stereo Lithography (SLA), Laminated Object Manufacturing (LOM). (Top, Şahin & Gökçe, 2019).

1.2 3D printers

As mentioned above, many 3D printers differ in size and the materials they use for printing.

They can be conditionally divided into two main categories: desktop 3D printers, which are widely used for teaching purposes, personal needs at home, and the production of small parts. These 3D printers are smaller, easy to use, and relatively cheaper.

The other category is for industrial purposes. They are used to manufacture various components in the automotive industry, aerospace and defence, healthcare, power and energy, etc. These printers are larger, perform more specific tasks, and use different materials (metal, ceramics, bio-products, fabrics, etc.) (Grand View Research, 2023; UltiMaker, 2023).

Tully and Meloni (2020) provide recommendations and guidelines on what printer to use, depending on the project's goals, the objects to be printed, and the planned costs. They describe the main features of the 3D printer, the materials that are used, and the stages that are gone through. When choosing a suitable printer, the authors advise researchers that it is necessary to consider the present and future use well, to balance between the financial side and time, benefits, and constraints. According to them, there are several **benefits** of 3D printing compared with traditional manufacturing:

- 3D printing reduces the need for external services and specialists, and creating some parts in-house is possible;
- Shorter production time for various items needed by the end user;
- Independence and freedom from the need for other machines, typically a 3D printer is sufficient to produce a complete end product.

3D printing reduces waste and creates individual spare parts that are hard to find and buy because they are out of use and do not require maintenance.

As a **challenge** and **disadvantage**, they pointed out that these new technologies could overwhelm new users with less experience.

1.3 3D printing software

Creating 3D designs requires specialized computer-aided design (CAD) software, which is mainly used in architecture, interior design, engineering projects, and computer games. Some programs are for professionals, while others are suitable for beginners in this field. Most are free, open-source, or browser-based, and some allow the transformation of a 2D image into a 3D object. The main criteria for choosing the best CAD software should be the user's experience level (Sculpteo, 2023).

Some of the best known and recommended for this purpose are Autodesk Fusion 360, Autodesk Tinkercad, OpenSCAD, Blender, NanoCAD, 3D Builder, 3D Slash, 3D Crafter, LibreCAD, etc.

Some CAD software programs are appropriate for educational purposes and suitable for kids, like LeoCAD, which uses Lego bricks to create 3D objects. Another one is BlocksCAD, which uses block commands and helps kids learn coding concepts and computational thinking.

Plenty of available 3D models can be downloaded for free or at an affordable price and modified to support educators and learners. This builds communities of people who share common interests.

Some of these platforms are **Cults** (Cults, 2023), **All3DP** (All3DP, 2023), and **Free3D** (Free3D, 2023), which offer a wide variety of 3D models in different categories.

UltiMaker Thingiverse (2023) has a rich collection of 3D models, divided by subject, including some designed for blind people.

Sketchfab (Sketchfab, 2023) is a leading web platform for 3D and AR, but most models are paid.

3DFindit (3DFindit, 2023) is a visual search engine for 3D CAD, CAE and BIM models using different filters. Users can upload their files and search for similar ones.

NIH 3D (NIH 3D, 2023) is an open, community-driven portal for downloading, sharing, and creating scientific and medical 3D models for 3D printing and interactive 3D visualization, including virtual and augmented reality.

NASA 3D resources (NASA 3D resources, 2023) has a collection of 3D models of lunar and planetary terrains, small space bodies, and a library of physical objects accessible to the visually impaired people. These models serve as a tool for introducing space sciences to the learners (Horowitz & Schultz, 2014).

1.4 Implementation of 3D printing

The development of the 4th industrial revolution and its associated concepts and technologies, such as robotics, IoT, machine learning, and others, contributes

to the increasing adoption and integration of 3D printing in various fields. For a long time, the aerospace, automotive industry, and healthcare have been applying 3D printing for prototyping and creating different parts of aircraft and cars, especially for the interiors because customization is possible.

According to statistical analyses and studies, 3D printing for prototyping has the highest relative share, followed by manufacturing and proof of concept. As the most used material is Fused Deposition Modelling (FDM), there is also an increase in Direct Metal Laser Sintering (DMLS) for creating metal components and Selective Laser Sintering (SLS) for the sector of consumers' goods (Fortune Business Insights, 2023).

The increase in the use of metal and ceramics for 3D printing is also justified by reducing the use of plastics to protect the environment.

Many food industry by-products need to be reused to reduce costs and environmental damage, leading to the increasing popularity of food printing. Some authors explore extrusion-based 3D food printing systems with in situ gelation and mixing. They find that these systems provide greater control over the final properties of the printed products (Álvarez-Castillo et al., 2021).

The widespread adoption of this technology in various areas also requires specialists in this field, because, according to the data, about 71% of companies do not feel sufficiently prepared and trained to use 3D printing effectively (Joshi, 2023).

The presented statistical data reveals the need for a good understanding of this technology to foster innovation and the ability to transform and grow businesses.

2. Adopting 3D printing in education

New technologies surround the latest generation of learners, and many are curious to explore and use them. This implies updating the teaching facilities, curricula and programs, acquiring new skills and enhancing the teachers' competencies. Applying active learning methods (learning by doing, problem-based learning, personalized and adaptive learning, project-based and inquiry-based learning, maker education and STEAM education, and online and blended learning) increases learners' motivation and enhances interest in the discipline. Many schools and universities have purchased 3D printers and equipped STEAM classrooms and centers.

Based on the research by (Alhamad et.al., 2019) and their experience and continuous practice, it could be assumed that students become more excited and enthusiastic when given the freedom to use 3D printing technologies in their coursework. This innovative process has generated much interest among students, who are thrilled to be involved in this area. They believe a specific 3D printing and scanning course should be assigned for different educational areas and specialties, especially mechanical engineering education.

According to (Ford & Minshall, 2019) and their study of possible ways to apply 3D printing in different educational institutions (schools, universities, libraries, and special education settings), six categories of implementing 3D printing have been identified: (1) to teach students about 3D printing; (2) to teach educators about 3D printing; (3) as a support technology during teaching; (4) to produce artifacts that aid learning; (5) to create assistive technologies; and (6) to support outreach activities.

Because this is a relatively new technology and is still limited, educational institutions have 3D printers. Many teachers are unfamiliar with it and need to be trained to introduce it to their students. If the teachers feel confident when using it, they will be able to implement it in their subjects appropriately. Their scoping review (Kit Ng et al., 2022) outlined pedagogical approaches that could be incorporated in mathematical education alongside 3D printing, such as project/problem-based learning, collaborative learning, and maker / design-based learning.

3D printers are being used to enrich STEM education through a variety of learning techniques and experiences. Reports of 3D-printed models for improved visualization of chemical phenomena, as well as the educational use of 3D-printed laboratory devices, are rapidly increasing (Pinger, Geiger & Spence, 2020).

Gitnux (2023) reported that 66% of education and research institutes use in-house 3D printers. This indicates that they know the need to incorporate this technology into teaching and learning in various disciplines.

One advantage of using 3D printing in education is that developing the creativity and practical skills to use this technology will prepare learners for the job market (LeapFrog, 2023).

Furthermore, acquiring new skills and integrating this technology with various disciplines, including medicine, architecture, art, design, engineering, and others is essential. Creating 3D anatomical models (Mamo et al., 2023), works of art, geographical objects, complex structures, and objects from different subject areas requires in-depth knowledge of the specific field.

3D printing is beneficial for blind people. Through 3D models, they can visualize and interpret content in graphical form. An organization and website, See3D, has been set up to organize the process of requesting, printing, and delivering 3D printed models for visually impaired people (blind people) (Karbowski, 2020). Creating tactile media and resources for blind people is of regional and national importance, and these assistive technologies will provide training for blind or visually impaired youth (Brulé & Bailly, 2021).

Another research study among students with blindness in a biology classroom in a primary school in Montenegro showed that students have a positive attitude towards 3D modeling and that this pedagogical approach through practical activities helped them acquire knowledge and their ability to describe cell parts and organelles. It increased their visualization of learning content, communication, and feeling of equality in participation. (Anđić et al., 2022).

The development of this technology and its applications in various fields has led to exploring the possible benefits and outcomes of integrating it into education, which has been evident in the last few years. Many authors present and share their experiences of applying 3D printing in different disciplines and possible ways to connect with other subjects, which are analyzed and summarized by (Novak et al., 2021). The authors present five significant guidelines and recommendations for a multidisciplinary approach for learning 3D printing:

(1) Prepare a new generation of engineers. Developing a new generation of engineers is crucial because 3D printing can create complex structures and innovative items that are difficult to make using other techniques. Because of its widespread use in engineering fields, the automobile industry, and the aerospace sector, proficiency in 3D modeling and printing processes is required

(2) Democratize additive manufacturing technology and production. Developments in this area help to democratize additive manufacturing production and technology. 3D printing is becoming increasingly integrated into many aspects of modern life due to the expanding availability of 3D printers and related materials and a significant drop in the price and time needed to create 3D models.

(3) Support learning using low-cost 3D-printed learning aids. The availability of free 3D modeling software and platforms for shared 3D models and resources provides opportunities for quick and easy prototyping and 3D printing of educational materials.

(4) Produce assistive technologies. 3D printing has enormous potential for creating assistive devices for humans and animals, such as prostheses and orthoses specifically adapted to the individual's needs, devices for people with visual impairments, and products for everyday use.

(5) Promote creativity and innovation. Students can create their projects, see the results, and print them using various materials. They are more enthusiastic and motivated when they can freely use 3D printing in their work.

3. Conclusions

Contemporary education requires updating the curriculum content and creating cross-curricular links, which is one of the main ideas and goals in STEAM education. Augmented and virtual reality, 3D modelling, and printing contribute to making learning content more accessible, immersive, and interactive. Increasingly accessible 3D desktop printers that can be used at home encourage creativity and learner activity. Creating a 3D model requires new skills and knowledge in different subject areas, making learning more effective.

The free software available to create 3D models, and the ability to download them from platforms with similar content supports teachers and learners alike. The flipped classroom learning model can be used, where learners prepare

independently at home on a topic and only discuss the main points they find difficult or need more explanation in class. Also, 3D printing is suitable for applying PBL (project-based learning), from researching and studying an object or phenomenon to creating and printing the 3D model. This builds teamwork skills, responsibility, and discipline.

Experts from different sciences (biological, life sciences, and others) must work together and learn from each other to adapt the learning content and curriculum to engage and motivate learners and teachers to be creators (Hansen et al., 2020).

A step forward in improving the curriculum in the Faculty of Veterinary Medicine at Trakia University, Stara Zagora, is to incorporate 3D printing in the elective subject “Informatics” and teach students how to benefit from this technology professionally.

Developing and applying 3D printing in education will be one of educational institutions' leading goals and objectives. It will also influence and be one of the key competencies in the era of the 4th industrial revolution (Chun, 2021).

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Virtual Reality in training: A multidimensional analysis of technologies, challenges and paradigms

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Abstract: *This paper explores the adoption of Virtual Reality (VR) and Extended Reality (XR) in professional training, demonstrating their potential to revolutionize learning by providing immersive, interactive environments that mimic real-world scenarios. Our review spans several sectors, including healthcare, engineering, and defense, and assesses how VR and XR enhance engagement, knowledge retention, and training efficiency. Results indicate that these technologies not only personalize learning experiences but also reduce costs and increase training accessibility. Finally, we present a framework for a multipurpose VR training application. The conclusion highlights the need for continued research to fully harness the capabilities of VR and XR in training programs.*

Keywords: immersive technologies, skill acquisition, virtual training, personalized learning, simulation environments.

1. Introduction

Virtual Reality (VR) and Extended Reality (XR) technologies are increasingly becoming vital tools in training across various sectors due to their unique ability to create simulated, controlled environments. This paper explores the application and benefits of these technologies in enhancing training programs, particularly focusing on areas where traditional training poses challenges due to safety, cost, or logistical issues.

Moreover, VR and XR technologies are transforming training across various sectors by creating simulated, realistic environments that mitigate physical risks. This evolution is further underscored by the emergence of the Metaverse, which extends these technologies into new realms of immersive interaction, potentially revolutionizing professional training programs (Petre et al., 2023).

The introduction of VR - entirely virtual environments - and XR - a blend of real and virtual elements into training frameworks allows learners to experience and interact with realistic scenarios without the risks associated with physical environments. For instance, in medical training, VR and XR can simulate surgical

procedures allowing trainees to practice without any danger to patients. Similarly, in fields like aerospace and defence, these technologies provide realistic yet safely controlled settings for practising complex operations, which would be difficult or impossible to recreate physically due to costs or safety concerns.

This paper reviews how these simulated environments can be tailored to meet diverse learning needs and styles, offering more personalized training options. By adapting the level of difficulty and the feedback in real-time based on the learner's performance, VR and XR can offer a more effective learning experience compared to one-size-fits-all training approaches.

Moreover, the immersive nature of VR and XR can lead to higher levels of engagement and retention of information. This is crucial in professional fields where mastering complex skills is essential and can be enhanced significantly through repeated practice in lifelike settings (Petre et al., 2023).

In addition to these educational benefits, the paper will discuss the broader implications of VR and XR technologies in training and development, including their potential to reduce costs associated with physical training materials and facilities, and how they can make high-quality training more accessible to a wider audience.

In the following sections, we will detail the methodology used to examine the current applications of VR and XR in training, present the results from recent studies, and discuss the potential future developments in this area.

2. VR training paradigms

VR training is a novel way of teaching which provides a level of immersion that traditional teaching methods can not. This is achieved by creating a realistic digital environment where learners can interact with objects and observe events using a VR headset and motion controllers. Additionally, this type of training can further incorporate technologies such as haptic gloves and vests or omnidirectional treadmills, adding an extra layer of immersion. Using VR technologies makes it possible to recreate real-life conditions that may otherwise be either too costly to replicate on a large scale or too dangerous to expose learners to. Furthermore, a digital environment can be used to recreate high-stakes scenarios such as surgeries or firefighting scenarios without any real-world consequences.

Traditional learning can be either pen-and-paper teaching or instructor-based teaching. Both these methods are widely used in educational training and produce theoretical knowledge through interactions with an instructor or with various teaching materials. In contrast to VR training, traditional learning lacks in several areas. First of all, these learning techniques are unable to replicate the level of realism that VR can. Furthermore, due to the nature of pen-and-paper teaching, there is little to no interactivity with the subject matter, it being more focused on theoretical knowledge (Biggs, 1999). By contrast, instructor-led training provides

some level of interactivity provided the instructor is knowledgeable on the subject matter (Salas et al., 2005).

VR training can be broken down into three categories: non-immersive VR training, semi-immersive VR training and fully immersive VR training. In non-immersive VR training learners are taught using traditional displays such as desktop screens and interact with the virtual environment using traditional input methods like keyboard and mouse. While not providing the same level of immersion as the other VR teaching methods, inhibiting the retention of information and lacking the practical experience, it is nonetheless more immersive than non-VR methods (Merchant et al., 2014). Since it does not require costly VR equipment, non-immersive teaching methods have some inherent advantages. Not requiring specialised equipment drastically brings down the costs associated with it, in turn making it easier to adopt as a teaching method.

Semi-immersive VR training is a step up from non-immersive training, utilizing multiple screens or large projectors to simulate an environment. Similar to non-immersive methods, there is no need for VR headsets to be set up however, depending on the subject matter being taught, the cost of screens or projectors can be higher (Issenberg et al., 2005).

Fully immersive training creates the most realistic and immersive VR experience. It utilises VR headsets and motion controllers, allowing the learner to fully interact with a digital environment. The high realism of VR training applications mirrors real-world scenarios and is the best for training in high-risk or enhanced stress fields such as medicine (Seymour et al., 2002). However, it is a somewhat limited method as its high setup cost can impede its wide adoption. Moreover, due to said high cost, it has a scalability problem, setting it up for a large group and having it be an efficient training tool being limited by the cost and larger area required to operate it. Lastly, retention is conditioned on the learner being comfortable with wearing VR headsets. Some users may experience discomfort from motion sickness after prolonged use, so it's not an effective teaching tool for everyone.

VR training can be further broken down in the way the training is achieved. All these methodologies serve different purposes and have a wide spectrum of objectives and learning outcomes. Scenario-based learning immerses trainees in an environment in which they must respond to challenges in real-time (Herrera, Bailenson, Weisz, Ogle, & Zaki, 2018). This method of training allows for repeat training of the same person without real-world consequences (Cumin et al., 2013), improving decision-making and situational awareness (Pottle, 2019).

In contrast to scenario-based training in which a hard skill is developed and enforced, soft skills such as communication and management can be learned through role-playing scenarios. Doing this in a realistic digital environment can be a safe space for people to practice difficult conversations (Slater & Sanchez-Vives, 2019). It can be more engaging than an offline role-playing exercise. However, one

drawback is that it is more difficult to evaluate one's skill as soft skills are prone to be highly subjective (Kothgassner et al., 2021).

If the objective is to teach a specific task, then the appropriate methodology is a task-oriented approach to teaching. This involves mechanical repetition of a specific task or group of tasks, ensuring skill retention through practice (Seymour et al., 2002). It is the best way to navigate hazardous courses, providing a safe space for the application of knowledge. It is however incompatible with a dynamic environment in which unpredictable variables can alter the scenario, being contextually inflexible (Cook et al., 2011).

Lastly, data-driven training uses AI algorithms and data analysis to alter the simulation, providing a dynamic training environment that is personalised to the learner's performance. Personalised learning can track patterns in learning and improve skill acquisition by constantly adapting to the student's needs (Makransky & Lilleholt, 2018). Moreover, generative AI technologies can accommodate students with learning disabilities or other special needs (Barbu et al., , 2025).

3. Applications of VR in training

Due to the benefits mentioned in previous chapters, numerous industries have chosen to implement VR training, including Medicine (surgeries, patient interaction, interactive learning environment), Phobia Treatment, Industrial Engineering-manufacturing, Aviation, First Aid Services (Ambulance), and Security Forces (Police, Military).

- **Medicine.** Following the COVID-19 pandemic, the lack of practical education among students in this field became evident. Studies on how students perceive information through VR applications have shown that the time required to learn the same information using traditional methods was cut in half (Barsom, Graafland & Schijven, 2016). Out of 177 students who participated in a case study (Wish-Baratz et al., 2020), 143 (81%) stated that VR-based learning offers more benefits. The main application studied was human body dissection. An example is the Dissection Master XR application, which uses photogrammetry-generated human body models. Users can view bodies at different stages of dissection and access information about body components by selecting them.
- **Phobia Treatment.** The primary treatment is in vivo exposure therapy, a form of cognitive-behavioural therapy based on the idea that unrealistic thoughts cause negative states and unpleasant behaviours. In each 60–90 minute session, the patient is exposed to a high-stress stimulus until the anxiety decreases (Freitas et al., 2021). VR Exposure Therapy allows patients to confront their fears in a virtual environment, with scenarios adapted to their progress. A study on a group of 10-15-

year-old children exposed to VR therapy for social phobia showed positive results. They participated in two scenarios: the schoolyard and the classroom, both with two difficulty levels: easy and hard (Gutiérrez-Maldonado et al., 2009).

- **Industrial Engineering.** This field depends on time and space, and the integration of other sciences has evolved with technological advancements. Implementing VR training aligns with the industry's goal of reducing resource consumption. A study conducted in Poland (Stecula, 2023) simulated a factory's production line change. Each step was accompanied by visual and audio cues — participants received voice commands with subtitles, and important process elements were highlighted in different colours. Additionally, task order and execution could be modified. VR training eliminates the need to halt production for personnel training, supporting efficiency. Moreover, VR allows multiple employees to be trained simultaneously in a safe environment compared to traditional methods.
- **Aviation.** A 1977 study conducted in the United States (Kocian, 1977) highlighted the need for flight simulators due to a reduction in pilot training hours caused by aircraft complexity, high operational costs, and funding limitations. Today, VR training resolves these issues by providing accurate depth perception, a 360-degree field of view, and multiple training modes, unlike older simulators. While past training simulators focused solely on piloting, modern VR simulators incorporate emergencies for pilots, flight attendants, and maintenance personnel. Additionally, training is monitored by an instructor, and students receive feedback on their performance.
- **Paramedics Training.** In 2018, a first aid training scenario was developed in the Czech Republic in collaboration with neighbouring countries to train ambulance personnel using VR for START (Simple Triage and Rapid Treatment) and METHANE (accident reporting via radio) methods in mass casualty incidents (Lochmannová et al., 2022). The VR training consists of multiple modules, each with different difficulty levels. The presence of visual and auditory stimuli enhances user experience, requiring participants to prioritize patients and apply medical procedures correctly. The scenario allows user freedom, with their actions influencing the situation's outcome.

4. Commonly used technologies in VR training

While discussing the various technologies employed in VR training, it is crucial to consider not only the immersive capabilities but also the security measures necessary to protect these digital environments. As highlighted by Zamfir et al. (2024), ensuring cyber resilience is essential, particularly in settings like

virtual classrooms where sensitive information and user data are prevalent. Their guide provides comprehensive strategies for securing virtual classrooms against potential cyber threats, which is vital for maintaining trust and integrity in VR training systems.

HMD (Head Mounted Displays) are the primary equipment for enabling Virtual reality immersiveness. These are wearable devices designed to deliver immersive visual and auditory experiences by positioning screens or optical systems close to the user's eyes. These devices are commonly used in virtual reality (VR), augmented reality (AR), and mixed reality (MR) applications, offering environments where users can interact with virtual content in real-time. There are different types of HMD, including:

- Tethered Headsets: These headsets, which offer high-end performance and graphics, are connected to a workstation (Console, PC, etc.). Examples include the Oculus Rift, HTC Vive, and PlayStation VR.
- Wireless Headset: These headsets are all-in-one devices that do not require a workstation. They feature a built-in CPU, display, and sensors. Examples include the Oculus Quest and Pico Neo. Some headsets require connecting a smartphone that acts as a display and CPU, while the headset provides the lenses and device support. Examples of such headsets are Google Cardboard and Samsung Gear VR.

Immersive VR equipment brings VR immersiveness to a higher level, allowing users to experience fully immersive virtual reality. This is achieved by using advanced hardware designed to enhance the realism and interactivity of virtual reality experiences by providing users with greater freedom of movement and tactile feedback:

- ODT (Omnidirectional treadmill) is a mechanical device that allows a user to perform locomotive motion in any direction. It will enable 360-degree movements such as walking, running, or crouching. For safety, it provides a low-friction surface and harness system.
- Wired Gloves contain sensors that capture hand movement and interaction data such as finger bending or activating a switch. Advanced wired gloves can provide haptic feedback that renders the feeling of realistic button clicks, vibrations, and impact simulations. Users can feel virtual objects' texture, shape, or resistance through vibration or force actuators.
- Motion capture suits are wearable devices that track the user's entire body movement to provide accurate avatars in virtual spaces. Like haptic gloves, these suits also provide haptic feedback, simulating impacts, temperature, or pressure for a more immersive physical experience.
- Tracking devices are specialized hardware or integrated systems designed to capture and interpret the movement of facial features and

eye movements in real-time. These devices use high-resolution cameras, infrared sensors, or depth-sensing technology. High-end HMDs integrate such sensors, allowing the monitoring of key facial points, such as the movement of the eyes, reflections from the cornea and pupil, eyebrows, lips, and jaw.

A game engine is a comprehensive software framework designed to streamline and facilitate the development of video games by providing essential tools and functionalities. These engines typically include a rendering engine for graphics, a physics engine for simulating realistic movements and interactions, audio processing systems, scripting capabilities, and asset management tools. Modern game engines like Unity, Unreal or GoDot often support both 2D and 3D game development with advanced features like ray tracing, global illumination, and real-time graphics rendering. They also provide cross-platform compatibility, allowing developers to deploy games on multiple platforms such as PC, consoles, and mobile devices with minimal adjustments. Many engines include integrated development environments (IDEs) and support for programming languages like C#, C++, or Python, enabling developers to script gameplay mechanics and behaviours. Additionally, game engines are increasingly leveraging artificial intelligence and machine learning for adaptive gameplay, procedural content generation, and improved non-player character (NPC) behaviour.

CAD (Computer Aided Design) refers to the use of software tools to create, modify, analyze, and optimize designs in various fields, including engineering, architecture, and manufacturing. CAD systems facilitate the creation of precise 2D drawings, 3D models, and detailed blueprints by providing a digital workspace with specialized tools for geometry creation, dimensioning, and annotation. These tools allow users to construct complex shapes, surfaces, and assemblies with high accuracy, utilizing algorithms for geometric modelling, solid modelling, and parametric design. CAD software typically includes features like constraint management, which ensures that design changes adhere to specified parameters, and simulation capabilities, which can predict the performance and behaviour of designs under real-world conditions. Popular CAD platforms, such as AutoCAD, SolidWorks, and CATIA, offer integrations with CAM (Computer-Aided Manufacturing) and CAE (Computer-Aided Engineering) tools, creating an efficient design-to-production pipeline.

3D Modeling is the process of creating a 3D representation of an object, character, or environment using specialized software. It involves constructing a digital mesh, which is made up of vertices, edges, and polygons, that define the shape and structure of the model. There are various techniques used in 3D modelling, including polygonal modelling (building objects through connected polygons), sculpting (shaping models like virtual clay), procedural modelling (using algorithms and parameters to generate models and photogrammetry (capturing multiple overlapping images of a subject from different angles to generate an accurate 3D model). Modern 3D modeling software, such as Blender,

Autodesk Maya, and 3ds Max, offers advanced tools for precision modelling, UV mapping for textures, and rigging for animation and tools like Agisoft Metashape, RealityCapture, Autodesk ReCap and Meshroom are commonly used in photogrammetry, offering robust features for refining, scaling, and exporting models. Photogrammetry also plays a significant role in geospatial analysis, where it is used in conjunction with drones or satellites for large-scale topographic mapping. Its efficiency, accuracy, and ability to capture fine details make it a powerful tool for creating high-quality 3D representations from real-world data.

5. Challenges of VR training

Like any other emergent technology, unavoidable challenges and disadvantages can be identified in VR.

There are several hardware limitations such as the cost of high-quality equipment like HMD, treadmills, powerful workstations and any other assets required to be fully immersed in the training scenario. Otherwise, VR training can provide limited haptic feedback in the absence of specialized VR hardware that can reduce the realism of tasks that rely on physical sensations. There is also a lack of standardization for different VR systems, hence, compatibility issues arise and it makes it challenging to create universal training programs. Another drawback is the HMD's short battery life; especially if intensive training is conducted, the battery cannot sustain the HMD for more than one hour.

Developing VR training programs requires many resources, such as skilled developers, designers, and experts in the subject matter. To be effective, VR training must accurately simulate real-world conditions. Poorly designed simulations may lead to unrealistic expectations or improper training.

Users unfamiliar with VR may require time to adapt to the interface and controls, potentially slowing down training. Some users experience nausea or dizziness (VR sickness) due to latency issues, unnatural movement or prolonged exposure.

6. VR training user perception

Understanding user perception of Virtual Reality (VR) training is crucial for assessing its effectiveness and identifying areas for improvement. Techniques like those discussed by Văduva et al. (2023), which involve web scraping and natural language processing, can be instrumental in analyzing user feedback across various platforms to gauge overall satisfaction and pinpoint areas for technological refinement and user interface improvements.

6.1 User experience and immersion

One of the primary benefits of VR training is its ability to immerse users in realistic environments that enhance learning through practical experience.

Immersion can be evaluated through both subjective user feedback and objective measures such as increased heart rate or galvanic skin response during training sessions. Studies indicate that higher levels of immersion correlate with improved learning outcomes, as users are more engaged and can practice skills in a context that closely simulates real-life scenarios.

6.2 Usability of VR training systems

The usability of VR systems is another critical aspect of user perception. This includes the ease of navigating through the VR environment, the intuitiveness of the interface, and the physical comfort of using VR hardware. Poor usability can detract from the training experience, leading to frustration and decreased learning effectiveness. Feedback from users often highlights the need for more intuitive controls and ergonomic hardware designs to reduce physical strain and enhance the overall user experience.

6.3 Learning enhancement through VR

Perceptions of learning enhancement involve trainees' views on how effectively VR training supports skill acquisition and knowledge retention compared to traditional training methods. User feedback generally reflects a positive view, with many trainees reporting faster learning curves and better retention of information due to the interactive and engaging nature of VR training. However, the effectiveness can vary depending on the design of the training program and the specific learning objectives it aims to achieve.

6.4 Satisfaction and acceptance

Overall satisfaction with VR training is influenced by factors such as the realism of the simulations, the relevance of the skills practised to real-world applications, and the perceived value of the training in improving job performance. Acceptance of VR as a training tool also depends on cultural attitudes towards technology and individual openness to new learning methods. Surveys and interviews with trainees reveal a broad acceptance of VR training, particularly among younger and more technologically savvy users, though some reservations remain among those less familiar with VR technology.

6.5 Challenges and barriers

Despite the positive perceptions, some challenges and barriers affect user experience with VR training. These include physical discomfort, such as motion sickness, which can affect long-term usability and learning outcomes. Additionally, the high cost of VR equipment and the need for technical support are seen as barriers to widespread adoption, particularly in resource-constrained settings.

7. A conceptual framework for VR training

In this section, we propose a conceptual framework for a fully immersive VR application that combines multiple aspects of the teaching methodologies outlined in section 2. This training simulation is aimed at training personnel on how to deal with multiple potentially dangerous situations without prior knowledge of the scenario they're going to be presented with. This would test their knowledge of the safety protocols, their decision-making under pressure and their reaction speed to a developing situation, as well as the efficacy of the protocols and procedures put in place for the said situations. The basic outline of this application is detailed in Figure 1.

The minimum hardware requirements for this training suite are one workstation powerful enough to run two applications at once, one wireless HDM and one ODT. The HDM must be wireless, as a wired one would be a safety hazard, as the wire could easily wrap itself around someone's neck. The workstation has to run two applications simultaneously: the simulation and the control panel from which the simulation is being controlled. Outside the learner, there also need to be 2 extra people to ensure the smooth operation of the training process. The first one is the operator, who controls the simulation by altering variables based on the performance of the learner and who can also see what's going on within the simulation i.e. can see what the learner is doing and the supervisor who ensures the safety outside the simulation, helps the learner get in and out of the ODT and makes sure everything is running smoothly.

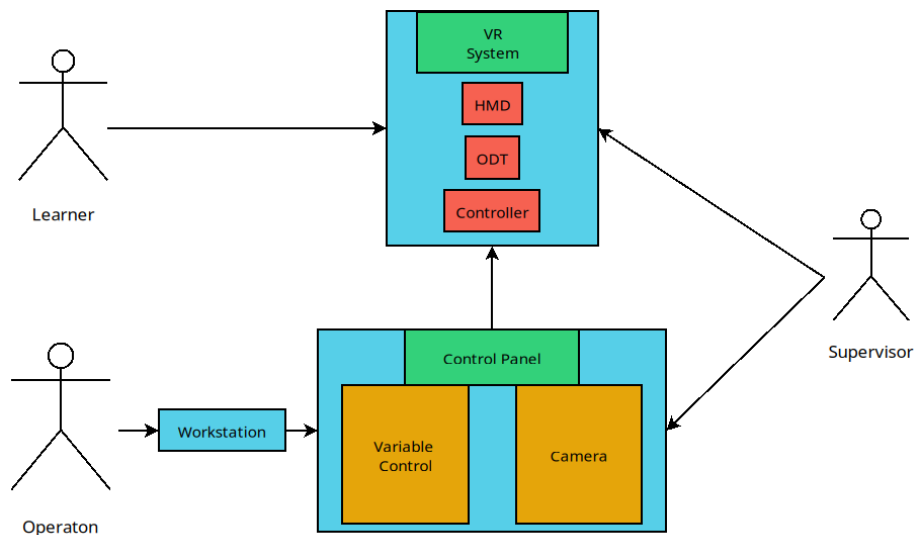


Figure 1. General workflow of all components of the conceptual framework.

Source: own research

The control panel is an essential component of the training simulation as it can activate different scenarios based on user experience, and manipulate certain environment objects and triggers. This program can also function as a stream listener, showing various parts of the scenario, functioning like a video surveillance system where the operator can examine the current training progress and freely adjust the scenario, as well as give verbal indications should the need arise.

With this conceptual framework, we aim to combine three different teaching methodologies. First, it is a scenario-based simulation, as it tests the decision-making abilities of the trainee under pressure in a given emergency scenario. It is also a task-oriented approach as it is within the realm of possibility that the operator can decide to repeat the scenario multiple times over, encouraging the development of muscle memory in these scenarios. Lastly, the simulation can be altered in real-time based on prior performance, personalizing it for the trainee.

8. Conclusion

User perception of VR training is generally positive, with notable benefits in immersion, learning enhancement, and user satisfaction. However, to maximise VR's potential in training environments, ongoing challenges related to usability, physical comfort, and accessibility must be addressed. As technology advances and more user feedback is integrated into VR training systems, these tools will likely become even more effective and widely accepted in professional training programs.

VR training developers have to take into account several costs that come associated with this teaching method when projecting their domain-specific application. This not only includes the tangibles such as equipment cost, physical space available and the processing power needed to run their software, but also intangibles namely user safety, comfort, disability support and a clear definition as to who and what the training is designed for. Our proposed framework incorporates multiple aspects of different training applications, making it easy to mould to any requirements.

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Exploring the potential of e-learning in economic crisis prediction

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Abstract: *This study explores e-learning’s potential to anticipate economic crises, positioning it as a key tool for global financial stability. By leveraging AI-driven text analysis — proven effective in financial forecasting — five predictive algorithms were assessed: exchange rate processing, logistic regression, linear regression, recurrent neural networks, and sentiment analysis. Using a 2008–2018 dataset, the goal is to develop an e-learning system that delivers reliable crisis predictions, enhancing proactive economic risk management.*

Keywords: e-learning, AI, economic crisis, predictive models, financial forecasting.

1. Introduction

This paper discusses the use of natural language processing (NLP) in e-learning, particularly for anticipating economic crises by analyzing public discourse. NLP has advanced to the point of “understanding” human language (Gîfu & Trandabăț, 2023; Alhawiti, 2014) and handling complex tasks such as stock price forecasting (Chelmuș *et al.*, 2018; Gîfu, 2020) and financial sentiment analysis (Li & Shah, 2017).

The study hypothesizes that public discourse, which reflects crises like political ones (Gîfu & Cristea, 2012), can be characterized through sentiment analysis (Gîfu & Cioca, 2014a/b; Delmonte *et al.*, 2012/2013) based on economic crisis triggers. To test this hypothesis, five deep learning algorithms (detailed later) were applied, focusing on the 2007 U.S. financial crisis, which quickly became a global downturn with recessions and credit collapse (Bach *et al.*, 2019; Hsu *et al.*, 2018). An economic crisis generally indicates a state’s inefficient economic management (Gîfu, 2015).

This research addresses a fundamental question: Can e-Learning and Public Discourse Analysis Prevent Economic Crises?

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To answer this, the RoMarketPulse tool was developed — an advanced NLP and machine learning application trained on an extensive corpus of economic news articles. This tool aims to predict imminent economic crises, starting with the 2008 global financial collapse, when major U.S. banks and financial institutions failed, by identifying early warning signals of financial instability.

The paper is structured as follows: Section 2 reviews existing approaches to economic crisis prediction. Section 3, the core of this study, details the proposed system, focusing on the dataset and deep learning methodology used to forecast global economic crises. Section 4 presents an analysis of the results and system performance, followed by concluding remarks in the final section.

2. Background

Before the 1980s, discriminant analysis was the primary method for bankruptcy prediction, later improved by combining it with logistic regression, achieving over 90% accuracy (Arora & Ravi, 2013; Svaboda et al., 2020). Currently, logistic regression remains widely used for assessing financial distress probability (Xiao et al., 2012; Li et al., 2017; Oz & Yelkenci, 2017; Ashraf et al., 2019), although the increasing nonlinearity of financial data (Ecer, 2013) has spurred the adoption of more sophisticated approaches. Backpropagation Neural Networks (BPNs) have been employed for bankruptcy risk classification (Aydin & Çavdar, 2015) and, in conjunction with discriminant analysis, for early economic crisis warning signals (Wang & Wu, 2017). In Romania, crisis analysis relied on semantic text classification until 2015 (Gîfu & Cristea, 2012).

Since the 1990s, Machine Learning (ML) and Deep Learning (DL) have become dominant forces in economic crisis forecasting, encompassing techniques like decision trees, hybrid classifiers, and ensemble models. Beyond these, the rapid evolution of DL has introduced powerful new architectures. Recurrent Neural Networks (RNNs), particularly those using character-level linguistic models, have demonstrated strong performance in stock market prediction (Pinheiro & Dras, 2017), showcasing the value of sequential data analysis.

However, more recent advancements in deep learning offer even greater potential. Transformer-based models, such as BERT (Devlin et al., 2018) and its successors, are now being explored for their ability to capture complex contextual relationships in financial text data, including news sentiment and expert commentary. Furthermore, the emergence of Large Language Models (LLMs) like GPT-3 (Brown et al., 2020) and LaMDA (Thoppilan et al., 2022) open new avenues for analyzing economic discourse at an unprecedented scale and understanding nuanced market sentiment. Even more cutting-edge approaches, like Quantum Natural Language Processing (QNLP), while still nascent, hold the promise of revolutionizing financial text analysis (Stein et al., 2023) through the power of quantum computing.

This study, focusing on deep learning, implements and tests five key methodologies to address its research question: 1) Currency exchange rate processing, 2) Logistic regression, 3) Linear regression, 4) Recurrent neural networks, and 5) Sentiment analysis. While acknowledging the rapid advancements in the field, this study focuses on establishing a strong baseline with established and effective deep learning approaches.

The main contributions of our research are as follows: extending the analysis to a broad spectrum of economic agents, including commercial sectors such as mobile telecommunications, information and communications technology (ICT), and service companies (Pop & Gifu, 2020; Pop et al., 2021/2022/2023); developing a heterogeneous data corpus, integrating content from social media alongside economic and business news sources; and the prototype system developed within this project, which enhances stock market fluctuation prediction accuracy, providing an advanced decision-support tool for both established and emerging companies.

3. Dataset and method

This section presents a method that analyzes how economic fluctuations are reflected in traditional mass media, including economic publications and specialized forums. It utilizes algorithms trained on a corpus of journalistic texts to identify key factors that can help predict an economic crisis.

3.1 Dataset

The RoNews dataset consists of 33,000 articles from newspapers, covering the period from 2008 to 2018. It is divided into two main categories: *economic* (from reputable economic publications) and *non-economic* (from social media). Each category is further split into three subclasses (see Fig. 1).



Figure 1. Dataset classes

Exchange Rate: Articles about events related to exchange rate discussions in Romania or abroad.

Capital Market (Budget): News items with data relevant to Romania's stock market, focusing on bank loans, real estate, and the IT industry.

Leftovers or Unclassified Data: Information that doesn't fit the core economic categories but offers valuable contextual insights. For example, cultural events like the Transilvania International Film Festival, while not directly affecting exchange rates or capital markets, may impact tourism and local businesses, contributing to the broader socio-economic landscape.

3.2 Method

For illustration, Figure 2 presents the RoMarketPulse architecture which is based on four modules to be described and exemplified.

Module 1: Data Collection and Acquisition; Article Validation

Data Collection: This module initiates the process by collecting relevant data from diverse online news sources. This encompasses the utilization of web scraping techniques for the extraction of articles from websites, APIs for news feed access, and/or press article databases.

Data Acquisition: Following initial collection, the data is stored in an appropriate format (e.g., TXT) for subsequent processing. This involves the organization of articles within a database, file system, and/or specific data structure.

Article Validation: To ensure data quality, a set of algorithms is applied to verify article coherence. These algorithms include grammar and orthography verification, detection of contradictory or unverified information, and comparison with other news sources to identify potential misinformation or errors.

Module 2: Corpus Segmentation and Article Preprocessing

Corpus Segmentation: Articles are grouped into thematic categories relevant to financial crisis analysis. These include categories such as “economy”, “finance”, “politics”, “social”, etc.

Article Preprocessing: Each article undergoes preprocessing tailored to its respective category. This includes the removal of irrelevant words (stopwords), text normalization (case conversion, punctuation removal), and segmentation into keywords or key phrases (tokenization), among other techniques.

Module 3: Data Preprocessing and Indicator Extraction

Data Preprocessing: This module employs specific algorithms to prepare the data for indicator analysis. This includes numerical data transformation, value scaling, outlier removal, and other relevant data manipulation techniques.

Indicator Extraction: Algorithms are utilized to identify and extract indicators associated with financial crises. These indicators can be of an economic nature (GDP, inflation, unemployment), financial (interest rates, exchange rates, stock market indicators), social (consumer confidence index), or political (political instability, governmental decisions).

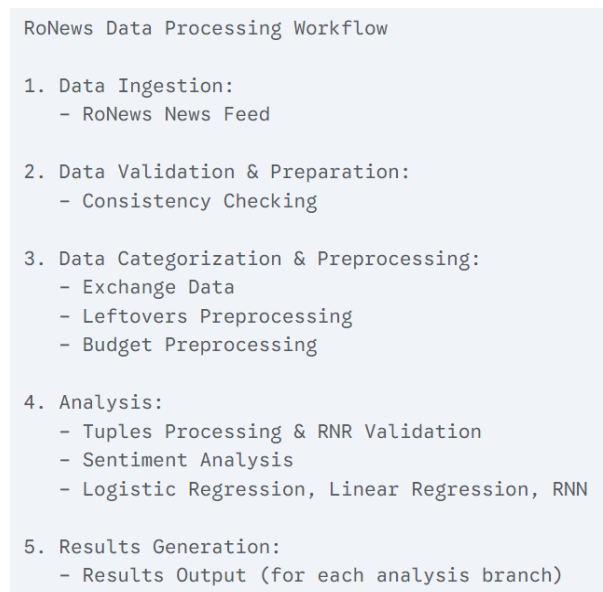


Figure 2. Data flow diagram

Module 4: Results Validation and Economic Crisis Prediction

Results Validation: The results obtained from indicator analysis are validated through diverse advanced analytical methods. This includes comparison with historical data, utilization of statistical models to evaluate prediction accuracy, and validation by experts in the field of economics.

Economic Crisis Prediction: Based on the validated results, the economic crisis prediction is generated. This involves the application of machine learning models, neural networks, and/or other artificial intelligence techniques that estimate the probability and timing of an economic crisis.

3.3 NLP pipeline

This section describes the core of the data preparation pipeline, encompassing several crucial steps to transform raw news articles into a format suitable for indicator extraction and subsequent analysis.

The process begins even before traditional “preprocessing” with a vital *Consistency Checking* phase. Before any further processing, a thorough, block-by-block verification is performed to ensure data consistency between the original data source and any replicas. This is crucial because, given the large volume of online news articles from diverse authors, text authenticity cannot be assumed. The consistency checking algorithm (utilizing the *IBM FileNet Consistency Checker*) serves two primary purposes: (1) Validating the authenticity of the RoNews corpus text; (2) Applying a set of preprocessing operations that eliminate duplicate and inconsistent texts.

This step is not merely desirable; it is essential. A significant portion of the original corpus was found to contain inconsistencies, plagiarized content, or even verbatim copies from external sources. The IBM FileNet Consistency Checker (FCC), integrated within FileNet Enterprise Manager (FEM), allows for this vital verification. While typically used for post-disaster recovery, its capabilities are invaluable here. FCC verifies that files in the repository match metadata in the CE database. This tool identifies semantic conflicts such as unused rules, rules lacking equivalents, redundant rules, conflicting rules, and conflicts between decision tables and trees. Specifically, it analyzes conflicts, redundancies, and equivalencies between rows in the same or different decision tables, leaves in the same or different decision trees, and combinations of rows, leaves, and action rules. As a direct result of this consistency check, the initial corpus was reduced from 33,000 to 30,800 articles, with the foreign exchange and real estate market sectors being most heavily impacted (2,200 articles removed due to duplication and inconsistency).

After consistency verification does the *standard preprocessing chain* begin. This phase starts with text segmentation and proceeds through tokenization, lemmatization, and part-of-speech (POS) tagging, leveraging the TreeTagger tool within the Python NLTK (Natural Language Toolkit) library.

The process involves:

1. Extracting content from the source TXT file (using UTF-8 encoding for Romanian diachritics recognition);
2. Data cleaning (removing links and extraneous symbols);
3. Syntactic analysis using the TreeTagger POS-tagger.

For exchange rate information, additional specialized steps are necessary: extracting potential date and monetary value indicators (RON, EUR, USD); identifying text events that can be linked to dates; and extracting numerical representations of monetary values in various currencies.

3.4 Method

Three submodules were considered, corresponding to each category in the RoNews corpus:

3.4.1 Exchange rate market

The first step was to extract all tuples of the form `<date, value in euros, value in dollars>` from the exchange rate dataset by applying the NBR (National Bank of Romania) validation algorithm.

It is important to note that the National Bank of Romania publishes monthly an XML file containing detailed information about the daily exchange rate of

currencies for a period of 15 years. This data is essential for analyzing currency fluctuations and for validating information from various sources. After applying the NBR validation algorithm, it was found that a very small number of values were incorrect. Thus, about 20 tuples were removed from the initial set due to identified inconsistencies.

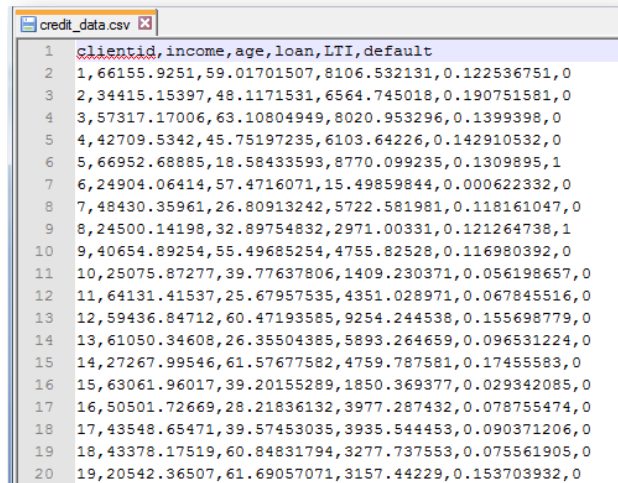
The results obtained after the NBR validation were carefully checked and, finally, all the correct data were stored in a CSV file, thus ensuring a solid database for the next steps of the analysis. This verified data is essential for any further processing or integration into other financial analysis systems.

3.4.2 Capital market

This module focuses on analyzing data from the RoNews corpus, classified under the “budget” category. The data was divided into three distinct subcategories, each with specific characteristics and processing algorithms: information on bank loans, real estate market data, and IT industry data.

A dedicated algorithm was applied for each of these subcategories:

- **Logistic Regression for bank loans** was implemented using Python 3.7, based on essential libraries such as python. Pandas and python.Sklearn. Logistic regression is a statistical model used to estimate the probability of a particular event, given the independent variables (relevant factors) that influence the dependent variable (what we want to predict). The algorithm measures the relationship between the input features and the desired outcome, thus allowing the estimation of precise probabilities in the context of bank loan prediction. The application of this algorithm took place on a set of approximately 7,330 files containing information about bank loans. After preprocessing and validation, 3,770 files were retained, considered to be correctly extracted and relevant for further analysis. After the preprocessing process, we have a CSV file which was used to train the logistic regression algorithm, thus ensuring a robust database for making accurate predictions and analyzing trends in the banking sector.
- **Linear Regression** for the real estate market was implemented in Python 3.7, similar to the previous approach. The algorithm was applied to a dataset comprising approximately 3,660 files related to real estate market transactions. After applying the extraction and validation process, only 2,240 files were correctly extracted and considered relevant for the real estate market analysis, thus ensuring the accuracy of the data used in the linear regression model. This algorithm is ideal for understanding the relationships between the various economic variables involved in real estate transactions and for predicting future developments based on them.



	clientid	income	age	loan	LTI	default
1	1,66155.9251	59.01701507	8106.532131	0.122536751	0	
2	2,34415.15397	48.1171531	6564.745018	0.190751581	0	
3	3,57317.17006	63.10804949	8020.953296	0.1399398	0	
4	4,42709.5342	45.75197235	6103.64226	0.142910532	0	
5	5,66952.68885	18.58433593	8770.099235	0.1309895	1	
6	6,24904.06414	57.4716071	15.49859844	0.000622332	0	
7	7,48430.35961	26.80913242	5722.581981	0.118161047	0	
8	8,24500.14198	32.89754832	2971.00331	0.121264738	1	
9	9,40654.89254	55.49685254	4755.82528	0.116980392	0	
10	10,25075.87277	39.77637806	1409.230371	0.056198657	0	
11	11,64131.41537	25.67957535	4351.028971	0.067845516	0	
12	12,59436.84712	60.47193585	9254.244538	0.155698779	0	
13	13,61050.34608	26.35504385	5893.264659	0.096531224	0	
14	14,27267.99546	61.57677582	4759.787581	0.17455583	0	
15	15,63061.96017	39.20155289	1850.369377	0.029342085	0	
16	16,50501.72669	28.21836132	3977.287432	0.078755474	0	
17	17,43548.65471	39.57453035	3935.544453	0.090371206	0	
18	18,43378.17519	60.84831794	3277.737553	0.075561905	0	
19	19,20542.36507	61.69057071	3157.44229	0.153703932	0	
20						

Figure 3. CSV file containing information about bank credits

Recurrent Neural Networks (RNNs) for the IT industry were implemented using the Python TensorFlow framework, which is very efficient in managing sequential data. RNNs are able to capture the temporal dependencies between the input data, which makes them ideal for analyzing news flows and financial market developments. However, during training, special attention was paid to managing the multiplication of gradients smaller than zero, to prevent learning errors and the phenomenon of vanishing gradient. The algorithm was trained on a set of approximately 4,400 news articles in the IT field, including relevant information about the IT industry and specific stock market indices for this sector. By applying recurrent neural networks, it was possible to identify significant trends in the evolution of this sector, providing useful and accurate forecasts in the context of the IT stock market.

3.4.3 Leftovers

This category includes approximately 6,960 files that could not be assigned to other economic categories mentioned previously. For the analysis of the files in the “leftovers” dataset, the use of sentiment analysis (SA) was chosen as an appropriate method. The implementation of sentiment analysis was carried out in Python, using a set of libraries, including Polyglot. Polyglot has polarity lexicons for 136 languages, including Romanian, and the polarity scale of words is based on three levels: +1 for positive words, -1 for negative words, and 0 for neutral words. This Python module proves useful in calculating a more precise score of the sentiment associated with an entity mentioned in a text. If the predominant sentiment is negative, specialists consider that news a signal of a possible economic crisis, given the context and nuances transmitted by the text.

4. Statistics

The prediction performance of the exchange rate processing algorithm (including NBR validation), the logistic regression algorithm, the linear regression algorithm, the recurrent neural network (RNN), the sentiment analysis model, and the RoMarketPulse result based on these algorithms are presented in Table 1.

Table 1. Values (Training Set)

Method	Precision	Recall	Accuracy
Exchange rate processing	0.78	0.78	0.78
Logistic Regression	0.74	0.73	0.77
Linear Regression	0.78	0.80	0.78
Recurrent Neural Network	0.73	0.75	0.73
Sentiment Analysis	0.85	0.81	0.85

This study (using training data from Table 1) evaluated several methods for economic prediction. Sentiment analysis performed best (around 85% accuracy), likely due to its ability to capture market sentiment from news and social media. Linear regression and exchange rate processing achieved good results (around 78 accuracy), suggesting strong correlations between economic indicators and target variables. Logistic regression had moderate performance (around 77% accuracy), possibly less suited to the data's complexity. Recurrent Neural Networks (RNNs) performed the worst (around 73% accuracy), potentially due to data limitations, the complexity of economic systems, overfitting, or suboptimal hyperparameter tuning. The study concludes that combining these methods, especially sentiment analysis with traditional statistical approaches, could create a more robust economic prediction system.

5. Conclusions

This research proposes a method for anticipating economic trends by analyzing past economic events, using a decade's worth of economic news articles from the ronews dataset. this approach has identified signs of the 2020 global economic crisis (COVID-19 pandemic) within the data, acknowledging a roughly two-year margin of error for such studies. The research aims to provide a valuable tool for decision-makers and contribute to building interactive economic study platforms for financial expertise and accessible economic education. Furthermore, it emphasizes the role of elearning and collaboration between economists, programmers, and nlp specialists in creating intuitive online platforms to make financial learning more accessible and relevant for the evolving global economy.

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Integrating Virtual Reality into engineering education: An interactive application for learning mechanisms

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Abstract: *This study presents a VR-based educational application designed to enhance students' understanding of mechanical systems, focusing on crank-slider mechanisms, oscillating slides, crank-piston systems, and four-bar linkages. The application integrates 3D models, animations, and interactive simulations, aligning with Bloom's Taxonomy to facilitate progressive cognitive development. A Virtual Instructor Drone provides AI-guided explanations, ensuring structured learning, while the Introductory Scenario familiarizes students with VR navigation and object manipulation. Students participate in piston assembly, engine integration, and dynamic motion demonstrations, reinforcing spatial awareness and practical skills. The FreeRoom Scenario promotes independent exploration, problem-solving, and creative thinking. Findings indicate that VR enhances engagement (28%), interactivity (26%), and visualization (16%). However, challenges such as initial adaptation difficulties (30%) and spatial orientation issues (9%) suggest the need for improved onboarding and navigation support. Future research will evaluate knowledge retention and skill acquisition through pre- and post-evaluation studies, using surveys and focus groups. By combining structured learning, hands-on interactivity, and real-time feedback, this VR-based approach effectively bridges theory and practice, providing an innovative solution for engineering education.*

Keywords: Virtual Reality, Engineering Education, Crank-Slider Mechanism, Interactive Learning.

1. Introduction

Virtual Reality (VR) has become a key technology in education, providing immersive, interactive learning experiences that significantly enhance student engagement and comprehension (Grigore & Turcu, 2024). Recent research has examined the integration of VR across various educational fields, including engineering, biology, and general pedagogy, emphasizing its potential to revolutionize conventional instructional approaches.

Engineering education integrates both theoretical foundations and hands-on applications. Traditional methods textbooks, 2D diagrams, and physical models

often fail to effectively convey the complexity of mechanical systems, hindering students' ability to grasp and visualize key concepts. Virtual Reality mitigates these challenges through immersive simulations, bridging the gap between theory and practice. This enables students to actively engage with and explore complex systems in a dynamic learning environment (Grigore & Turcu, 2024).

This paper presents a VR-based educational application centered on the crank-slider mechanism, a fundamental component in engines and industrial machinery. Mastering this mechanism is essential for mechanical engineering students. The VR application enables users to interact with it, observe its motion dynamics, and conduct virtual experiments in a controlled, risk-free setting. This study aims to outline the development process of the VR tool and examine its potential applications in engineering education. Furthermore, the application aligns with Bloom's Taxonomy, supporting a structured learning progression from foundational knowledge acquisition to the development of advanced cognitive skills.

2. Literature review

Virtual Reality in education is rooted in theories emphasizing experiential learning and active engagement. Abbas Shah et al. (2024) and Grigore & Turcu (2024) argue that incorporating educational frameworks into VR-based laboratories enhances learning outcomes by providing immersive experiences that foster knowledge construction and personalized learning. Their analysis underscores the importance of aligning VR applications with established pedagogical models to optimize their educational impact. Similarly, Morimoto & Ponton (2021) suggest that VR revitalizes naturalistic teaching methods by enabling students to actively explore biological concepts in virtual environments, enhancing their observational and analytical skills.

Research has examined Virtual Reality's role in engineering education, emphasizing its effectiveness in simulating complex real-world scenarios. Han (2023) notes that traditional teaching methods often struggle to convey abstract engineering concepts, whereas VR provides a more intuitive and interactive learning experience. Similarly, Halabi (2020) supports this view, showing that integrating VR with project-based learning enhances students' problem-solving skills and fosters teamwork. Their study found that students engaged in VR-based engineering design projects demonstrated superior conceptual understanding and practical application compared to those using conventional methods.

Abulrub, Attridge & Williams (2011) highlight VR's potential to foster creativity and innovation in engineering education. Their study suggests that VR-based simulations enable students to explore and visualize engineering concepts in a controlled virtual environment, enhancing spatial awareness and technical skills. Similarly, the growing adoption of VR in engineering education is driven by its effectiveness in bridging theoretical learning and real-world applications, as noted in *Virtual Reality in Engineering Education* (2011).

Beyond engineering, VR is increasingly recognized as a valuable tool in science education. Morimoto & Ponton (2021) highlight VR's role in evolutionary biology, where virtual field trips and simulated ecosystems provide students with unprecedented opportunities to engage with biological phenomena. Their study underscores VR's capacity to enhance traditional fieldwork by providing controlled, interactive environments for examining ecological and evolutionary processes. Nasrullah et al. (2024) further highlight the growing role of VR in education through a bibliometric analysis, revealing a significant increase in scholarly interest over the past decade. Their findings suggest that VR is increasingly regarded as a viable alternative to traditional multimedia learning tools, particularly in STEM education.

Despite VR's well-documented benefits in education, several challenges impede its widespread adoption. Criollo-C et al. (2024) identify cost, accessibility, and technological limitations as major obstacles to implementation. Although VR hardware costs are declining, many educational institutions continue to face financial constraints and limited technical expertise, hindering effective curriculum integration. Grigore & Turcu (2024) suggest that familiarity with online platforms moderately influences students' perceptions of VR as a beneficial learning tool, indicating that prior digital engagement facilitates VR's integration into education.

A key challenge is developing VR content that aligns with pedagogical objectives. Halabi (2020) underscores that while VR can enhance learning outcomes, its effectiveness hinges on instructional design quality and its ability to engage students in meaningful learning experiences. Similarly, Abbas Shah et al. (2024) emphasize the need to anchor VR-based learning environments in sound educational principles to maximize impact and achieve learning objectives.

3. Methodology and technologies used

This section details the development of a VR application aimed at providing an interactive and immersive learning experience. The application familiarizes students with VR technology while teaching the crank-slider mechanism, a core engineering concept. The development followed a structured approach to ensure educational accuracy and pedagogical relevance. The key pre-development phases included the following:

1. Collaboration with the Supervising Professor: An academic expert oversaw the project, defining educational objectives and emphasizing VR's significance in engineering education. The crank-slider mechanism was selected as the focal topic for its relevance and educational value.

2. Research on the Crank-Slider Mechanism: Consultations with the professor ensured the accuracy of the educational content. Key information gathered included: Theoretical principles of the mechanism; Main components and their functions; Practical engineering applications; Animations developed using Linkage software.

3. Design and Evaluation of Learning Scenarios: Various scenarios were developed, from basic simulations to complex interactive experiences. These scenarios were evaluated based on: Pedagogical relevance; Interactivity level to enhance engagement; Practical application of theoretical knowledge.

4. Defining Application Objectives: Educational goals were clearly defined to uphold academic rigor. The objectives included: Interactive teaching of the crank-slider mechanism; Providing a safe environment for experimentation; Enhancing student motivation and engagement through immersive learning.

3.1 Application development

This VR application provides students with an interactive and practical approach to understanding the crank-slider mechanism in a safe virtual environment. Developed for Meta Quest 2, it incorporates structured educational scenarios, immersive interactions, and hands-on activities to reinforce theoretical learning:

- VR Familiarization: An interactive tutorial introduces students to Meta Quest 2, guiding them through fundamental interactions;
- Immersive Learning Environment: The app integrates visual, auditory, and interactive elements to foster an engaging and dynamic experience;
- Structured Educational Scenarios: Content is systematically structured to enhance accessibility and comprehension;
- Practical Skill Development: Interactive exercises, such as assembly and analysis, allow students to apply theoretical knowledge in a hands-on setting;

Developed using Epic Games' VR template, the app integrates customized mechanics, such as object manipulation, to enhance interactivity. Existing functionalities were adapted to align with educational objectives, ensuring seamless integration of interactivity and pedagogy. The VR scene was carefully designed to balance immersion and usability. Its layout maximizes space for interaction while preserving visual clarity. Performance factors, such as scene scale and graphics quality, were prioritized to ensure smooth operation on Meta Quest 2.

3.2 Virtual instructor

A virtual drone serves as an instructional guide, enhancing engagement and interactivity in the VR learning environment. This AI-driven assistant provides real-time guidance, explanations, and visual support, fostering a structured and immersive educational experience.

Key Features and Functionalities:

- Audio Instructions: AI-generated voice guidance with synchronized subtitles improves accessibility;
- Integration in the educational scenario: The drone actively explains technical concepts, such as the crank-slider mechanism, reinforcing comprehension;
- Visual Support: A virtual screen strategically displays relevant data alongside verbal explanations;
- Interactive Guidance: Step-by-step assistance in practical exercises enhances learning efficiency and hands-on application.

A key feature of the drone is its dynamic student interaction capability. The drone continuously tracks the student's position, maintaining proximity throughout the lesson to ensure ongoing support. Using the FacePlayer function, the drone dynamically adjusts its orientation with `FindLookAtRotation` and `SetWorldRotation`, ensuring it consistently faces the student for an intuitive and responsive learning experience. The drone navigates to predefined locations, structuring the lesson flow and guiding students through key educational points in the VR environment. This feature improves lesson organization while maintaining student engagement and focus on educational content.

Additionally, Unreal Engine 5 audio assets natively support subtitles, ensuring precise synchronization between spoken instructions and on-screen text. By integrating AI-driven guidance, dynamic movement, and structured interactivity, the drone functions as a key facilitator in VR-based learning, enhancing student engagement and comprehension.

3.3 Introductory scenario

The introductory scenario facilitates students' transition into VR learning, reducing barriers and building confidence in using VR equipment. This stage establishes a structured and engaging foundation, ensuring accessibility and a smooth progression to advanced educational modules. The drone-based virtual instructor is essential for student orientation. Through dynamic positioning, auditory guidance, and synchronized subtitles, it: Directs user attention to relevant 3D objects; Provides step-by-step instructions for VR interactions; Enhances engagement by acting as both an information source and interactive element.

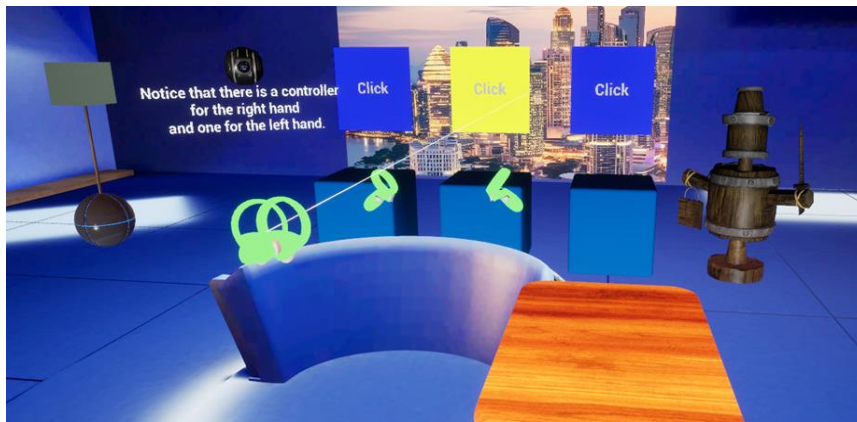


Figure 1. Introductory scenario

This scenario (Figure 1) familiarizes students with the VR environment and controllers, facilitating a smooth transition to more advanced educational tasks. It introduces core interactive activities that cultivate essential VR navigation and interaction skills. A key activity, object manipulation and selection, enables students to engage in hands-on interactions, learning to effectively use VR controllers for selecting and handling virtual objects. Additionally, Navigation and Movement training instructs students on traversing the VR environment using controller inputs, reinforcing spatial awareness and control.

To enhance mobility and reduce motion sickness, the scenario incorporates teleportation, enabling seamless movement between locations in the VR space. This feature enhances comfort and accessibility, particularly for users unfamiliar with virtual reality navigation. Students develop perspective control, adjusting their viewpoint naturally by rotating their head or using controller inputs for precise modifications. Additionally, object interaction and action triggers refine motor skills by instructing students on grasping, moving, and manipulating objects to activate mechanisms or complete specific tasks.

A key component of this scenario is controller familiarization, providing a structured introduction to VR controller functions. Visual and auditory cues provide step-by-step guidance, reinforcing students' understanding of VR interactions. This introductory phase employs a progressive learning approach, ensuring students develop confidence and competence before progressing to advanced educational tasks. Structured activities and interactive guidance maximize engagement and comprehension, significantly enhancing the VR learning experience.

3.4 Educational scenario

After the introductory phase, the educational scenario becomes the core of the VR system, providing an interactive and engaging learning experience. It deepens students' understanding of the crank-slider mechanism and related

systems, allowing them to apply theoretical concepts in a virtual hands-on setting. The VR-based application incorporates detailed 3D models and animations to support exploration of crank-slider mechanisms, double oscillating slides, crank-piston systems, and four-bar linkages. Animations and interactive elements offer clear visualizations of mechanical operations, making complex concepts more accessible and intuitive.

Students engage in hands-on interactivity, manipulating 3D components in real time. This feature reinforces practical mechanical insights while deepening students' understanding of mechanical systems. Additionally, visual aids, including informative images and animations, are displayed on a virtual screen to enhance concept retention and comprehension. Multiple-choice tests assess students' grasp of key concepts before progressing to advanced topics. These assessments evaluate comprehension and reinforce foundational knowledge, ensuring a structured learning progression.



Figure 2. Educational scenario

During the Piston Assembly & Engine Integration phase (Figure 3), students assemble a piston and integrate it into a virtual engine using VR controllers. This hands-on experience improves spatial awareness and mechanical precision, equipping students for real-world applications. Real-time visual and auditory feedback confirms correct actions and sustains engagement throughout the learning process. This reinforcement enhances retention and builds student confidence. Finally, an animated engine simulation illustrates how piston movements produce rotational motion, reinforcing students' understanding of mechanical transformations.

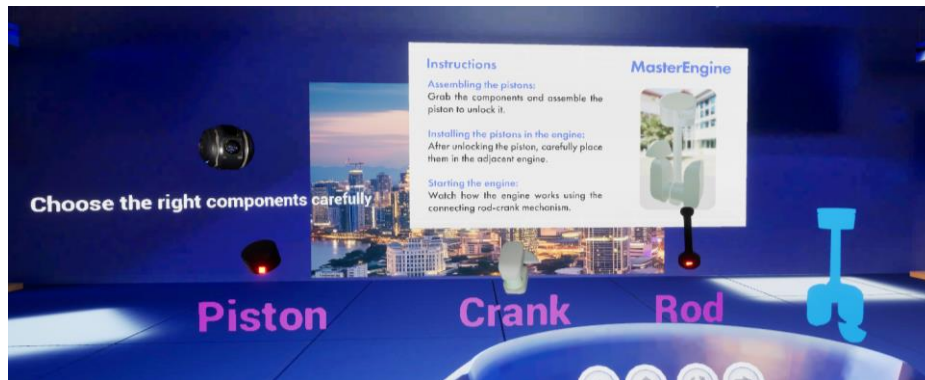


Figure 3. Piston assembly task

This VR-based educational scenario provides an interactive and immersive learning experience in engineering. By integrating structured guidance, hands-on engagement, and real-world applications, it effectively bridges theory and practice. VR technology enhances comprehension, retention, and skill development, establishing it as a valuable tool in modern engineering education.

3.5 Integration with Bloom's Taxonomy

VR educational scenarios are structured in alignment with Bloom's Taxonomy to ensure an effective learning experience. This framework classifies cognitive learning into six hierarchical levels. The application systematically covers each domain, as detailed in the following breakdown:

- **Remember (Knowledge Acquisition):** The educational scenario presents fundamental engineering concepts using structured explanations, animations, and real-time 3D visualizations. The Virtual Instructor Drone reinforces learning through AI-generated voice instructions and synchronized subtitles, guiding students step by step;
- **Understand (Conceptual Comprehension):** Dynamic simulations enable students to explore mechanical interactions and visualize component relationships. The Knowledge Testing for Advancement phase reinforces conceptual retention through interactive quizzes with real-time feedback;
- **Apply (Practical Implementation):** Comparative analysis in the educational scenario enables students to differentiate between crank-slider and similar mechanisms. The FreeRoom scenario supports independent exploration, guiding users in identifying key functional differences between mechanical structures;
- **Analyze (Comparative and Structural Understanding):** The educational scenario enables students to conduct a comparative analysis, differentiating crank-slider from similar mechanisms;

- Evaluate (Critical Thinking and Decision-Making): The knowledge testing for advancement phase promotes self-assessment and critical thinking before progression;
- Create (Synthesis and Innovation): The VR application fosters creativity by enabling students to reconstruct mechanical assemblies and explore new configurations.

4. Results

This section examines student feedback on VR technology in education, based on responses from 43 participants who completed the VR scenarios. Table 1 presents the response rate and abstentions, providing an overview of participant engagement and the dataset used in this analysis.

Table 1. Response rate and abstentions

Question	Responses	Abstentions
1 The best aspects	33 (77%)	10 (23%)
2 The most difficult aspects	19 (44%)	24 (56%)
3 Suggestions for improvements	24 (56%)	19 (44%)

1. Best aspects of using VR in learning

Students highlighted key benefits of VR technology in education. Thematic analysis of responses (Table 2) identifies four key themes: attention capture, interactivity, realism and visualization, and concept clarification.

Table 2. Thematic analysis of feedback on positive aspects

Theme	Frequency	%	Example responses
Capturing attention	12	28%	"Maintaining attention and interest was much easier."
Interactivity	11	26%	"Direct interaction with various mechanisms is great."
Realism and visualization	7	16%	"The experience was realistic, and the clear visuals clarified my ideas."
Clarifying concepts	3	7%	"Visualizing technical concepts helped me understand better."

The most frequently cited benefit (28% of students) was VR's capacity to capture and sustain attention. Students reported that VR made lessons more engaging and dynamic, helping them maintain focus throughout the learning experience. Additionally, 26% of participants cited interactivity as a key strength, noting that direct engagement with mechanical systems and hands-on simulations improved their learning.

VR's realism and high-quality visualizations (16% of respondents) were seen as crucial for enhancing understanding, providing clear and tangible representations of theoretical concepts. Although cited by only 7% of students, VR's ability to clarify complex technical ideas was considered a significant advantage, with direct visualizations aiding comprehension.

2. Challenges in using VR for learning

Although students recognized VR's benefits, they also identified challenges (Table 3). The most frequently cited challenge (30% of participants) was the initial adaptation phase. Many students found the first 3–5 minutes of VR use particularly challenging as they familiarized themselves with the controls and interface. This highlights the need for enhanced onboarding tutorials to ease the learning curve.

Table 3. Thematic analysis of feedback on difficult issues

Theme	Frequency	%	Example responses
Initial Adaptation	13	30%	"The first 3-5 minutes of use are more difficult until you adapt."
Spatial Orientation	4	9%	"Lack of attention to space and risks in confined space."
Technical Issues	2	5%	"Sometimes it freezes."

The second most reported challenge (9% of students) was spatial orientation. Some participants reported difficulties in maintaining awareness of their physical surroundings, particularly in confined spaces. These findings underscore the need for safety guidelines and virtual boundaries to prevent unintended movement or collisions. Less commonly, 5% of students experienced technical issues, including occasional software freezing, which disrupted their learning experience.

3. Suggestions for improving the VR learning experience

Students offered suggestions to enhance VR-based learning (Table 4). The most frequently suggested improvements focused on technology optimization and expanding educational scenarios, each cited by 19% of respondents.

Table 4. Thematic analysis of feedback on improving the VR experience

Theme	Frequency	%	Example responses
Technology Optimization	8	19%	"Better resolution for understanding the text."
Additional Scenarios	8	19%	"More lessons and educational scenarios should be developed."
No Changes	6	14%	"I wouldn't change anything; the interaction was immediate, and I look forward to more experiences like this."
More Intuitive Controls	2	5%	"I would adopt glove-based controls."

For technical improvements, students requested higher resolution for clearer text and visuals, highlighting the role of display quality in information retention. Additionally, participants suggested diversifying educational scenarios, noting that an expanded curriculum could enhance VR learning's versatility and applicability. Notably, 14% of students expressed satisfaction with the current implementation, stating that no major changes were necessary. This positive feedback reinforces the effectiveness of the interactive design. However, 5% of students proposed more intuitive control systems, such as glove-based interactions, to improve usability and ergonomics.

Students' feedback highlights both the strengths and challenges of using VR technology in education. Key benefits include enhanced engagement, interactivity, and improved visualization of complex concepts, whereas initial adaptation, spatial awareness, and technical stability require improvement.

5. Conclusions and future work

This study examines the educational impact of a VR-based learning environment aligned with Bloom's Taxonomy, aimed at enhancing engagement, knowledge retention, and skill development. Although formal testing is pending, student feedback emphasizes the application's immersive and interactive nature, noting its superiority over traditional teaching methods.

Key benefits identified include:

- Engagement: 28% of students praised VR's capacity to sustain attention, making lessons more dynamic;
- Interactivity: 26% of students highlighted that direct interaction with mechanical systems enhanced understanding;
- Visualization: 16% of students noted that realistic 3D representations improved the clarity of complex engineering concepts.

In addition to engagement, knowledge retention emerged as a key outcome. The application's multi-sensory learning approach, integrating visual, auditory, and kinesthetic elements, effectively reinforced engineering principles. Structured animations and interactive tutorials delivered clear explanations, fostering deeper and more enduring comprehension. However, 9% of students reported spatial orientation difficulties, highlighting the need for improved navigation guidance and safety features.

For practical skill development, the Piston Assembly and Engine Completion phase offered hands-on experience, enabling students to manipulate mechanical components and apply theoretical knowledge in a realistic setting. The FreeRoom Scenario promoted independent exploration and problem-solving, which students valued for fostering analytical thinking and design innovation. Although uncommon, 5% of students reported occasional technical issues, including software freezing, indicating a need for system stability optimization to improve the learning experience.

This study's findings align with prior research on VR's benefits in education, reinforcing the advantages of immersive learning environments. The results show that students perceived VR-based learning as more engaging and interactive than traditional methods, aligning with Han (2023) and Halabi (2020), who highlighted VR's role in enhancing student motivation and conceptual understanding. While Criollo-C et al. (2024) identified cost and accessibility as primary barriers to VR adoption, this study introduces empirical feedback through thematic analysis and emphasizes user-experience limitations that can be mitigated through design improvements.

Although this VR-based educational application shows strong potential in engineering education, further research is needed to assess its effectiveness and

impact. Future research will involve quantitative assessments of knowledge gain, task performance, and interaction efficiency, as well as qualitative studies on usability, engagement, and perceived learning benefits.

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Leveraging AI for the promotion of digital culture among young generations: A holistic approach to achieving SDG 11.4 on the safeguarding of cultural heritage in the digital age

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Abstract: Artificial Intelligence (AI) is changing how we perceive and preserve our cultural heritage and acts as a considerable impetus for the engagement of younger generations in the digital transmission of cultural identity, in accordance with Sustainable Development Goal (SDG) 11.4. AI-based methods (e.g., deep learning-based approaches for image recognition, natural language processing for linguistic heritage, generative AI for cultural reconstruction) not only add a new dimension to our perception of our own culture, but also allow us to preserve, analyze, and restore tangible and intangible heritage. Neural networks are used to restore missing or damaged artifacts, and AI-based computational ethnography deepens our understanding of both historical and sociocultural contexts. Corporate and institutional efforts bolster AI's influence on cultural sustainability. Google Arts & Culture uses deep learning with ultra-high-resolution archival images of your favourite work to create interactive virtual enhancement of the work to promote digital cultural literacy. To combat this, some suggest deploying AI to preserve cultural landmarks; UNESCO already uses AI-powered heritage monitoring systems to evaluate the effect of climate change and human activity on historical locations, using predictive analytics to identify how best to proactively preserve sites. Throughout all this, empirical evidence continues to emerge, reinforcing AI as an indispensable tool in the preservation of global heritage. AI-assisted methods to achieve digital documentation have shown statistical analyses in which most of the (known) cultural heritage sites (above 50%) have faster documentation for conservation. Furthermore, sentiment analysis of digital engagement patterns shows that AI-curated cultural content increases interest and retention rates among the youth, virtually up to 40%. AI, a new milestone, provides solutions of conserving oasis without structure. The resilience that emerges from the synergy between AI and heritage sciences can ascertain the ascending generation to generation transmission of cultural identity, in accordance with the long-term perspective envisioned in SDG 11.4 that facilitates the shaping of democratic values, share knowledge and practices on sustainable development as a holistic approach of dealing with the great transition era.

Keywords: Artificial Intelligence (AI), Digital Heritage Preservation, Computational Ethnography, Cultural Sustainability, Youth Engagement, Machine Learning in Cultural Conservation.

1. Introduction

Artificial intelligence (AI) has made incredible progress in recent years, bringing along radical changes in many facets of modern life — including the dissemination and conservation of cultural heritage in the digital era. AI and cultural heritage has opened up new pathways to protect historical pieces of interest, and democratize engagement with cultural knowledge, and engagement with younger generations. Aligned with Sustainable Development Goal (SDG) 11.4, which advocates for the protection of cultural and natural heritage, AI is a key facility in communication with Global Assets (United Nations, 2015). Techniques like deep learning, computer vision, and natural language processing — collectively known as A.I. New studies have investigated how AI can be employed to digitizing historical manuscripts, reconstruct artifacts and create interesting and immersive experiences through augmented and virtual reality (Pansoni et al., 2024).

Also, ethics will continue to play an important part in the application of AI within cultural heritage. AI-driven solutions, also raise many challenges in terms of data privacy, digital bias and the commodification of cultural knowledge (Silva & Oliveira, 2022). The recently announced Recommendation on the Ethics of Artificial Intelligence also emphasises the need for inclusion and transparency in technologies used for heritage preservation, among others (UNESCO, 2021). In this matter, the researchers claim that AI must be used as an augmentative tool, not a substitute for human expertise, so that technology mitigations do not disregard cultural values and moral principles (Gîrbacia, 2024). While AI will be addressed as a key transformative power in fostering young generations' digital culture, aligning with SDG 11.4, the paper will explore challenges within its ethical implementation.

2. Literature review

Artificial intelligence (AI) is increasingly being recognized for the transformative potential it holds as a tool for cultural heritage documentation, analysis, and engagement. The role of artificial intelligence is closely related to the Sustainable Development Goal (SDG) 11.4, which urges the strengthening of efforts to protect cultural heritage (United Nations, 2015). Such advancements in power and accessibility of AI technologies, especially with the use of machine learning and deep learning, have also prompted their increased use in heritage conservation, with automation in artifact classification, damage detection, and digital restoration (Münster et al., 2023). Research highlights AI's ability to handle more considerable datasets, revealing patterns that design conservation (Gîrbacia, 2024). A critical overview of AI uses in preservation of cultural heritage illustrates its involvement in the digitisation and restoration of cultural artefacts. Advances in AI-powered image recognition and 3D modeling further improve our understanding of heritage sites and their historical development (Ju, 2024). The

project mentioned, CEPROQHA, demonstrates how deep learning can classify and annotate cultural data that have missing gaps due to incomplete historical records (Belhi et al. 2023). Likewise, Runardotter (2011) elaborates why the organizational cooperation must be structured, in order to further implement the specific methodologies regarding the methods of digital preservation in heritage institutions. Additionally, AI has played a vital role in generating datasets of high quality for the protection of intangible cultural heritage, including native music, allowing for the preservation of diverse regional and ethnic trending art forms for future generations (Chen et al. 2024);

During this high-tech age of limitless connectivity, social learning and connected learning, we are looking at the changing face of education and employment as AI technology finds its way into every corner of our civilization, and becomes part of our daily lives (Jora et al., 2024). Consider the dual requirements of technological adaptation and socio-economic resilience that the broader cultural economy must face, already subject to global crises materializing as climate change, pandemics or geopolitical conflict (Jora et al., 2023).

To sum up AI has a lot of potential to the cultural heritage in terms of its preservation and engagement be it digitization and analytics or interactive experiences. Therefore, although its integration links well to SDG 11.4, we should remain alert and responsible to ensure the ethical applications of AI for inclusiveness. AI-enhanced cultural pari-passu conservation of historical events will thus potentially introduce more socio-cultural quandaries that future research can certainly tackle by building upon AI methodologies and technologies realizing a far more culturally conscionable program for safeguarding even a greater breadth of material than ever before while also potentially historical integrity and maximizing public access.

3. Research questions

UN-Centered Query To what extent do United Nations heritage reports and datasets—such as UNESCO World Heritage Centre’s planetary reports—effectively measure and evaluate the impact of AI-driven programs on the preservation and accessibility of tangible and intangible heritage for young audiences?

AI Motors and Predictive Models – Case Study What impact do GPT-based systems have on the diffusion of cultural heritage content, and what precarious predictions from the emergent predictive models exist for the future of youth engagement in digital culture?

4. Research methodology

We chose the mixed methods research methodology for this study, which enabled us to conduct a multi-dimensional assessment of AI-powered digital

cultural engagement of youth in terms of SDG 11.4. Using four key research questions, the study successfully explored theoretical frameworks, data-driven insights, UN reports, and AI-based predictive models.

Quantitative Analysis

Statistical analysis was performed in this study to determine the impact AI affected youth engagement with digital culture. Data came from the UNESCO Institute for Statistics and Eurostat, gauging effectiveness of AI-enabled initiatives like virtual tours and AI-curated archives, etc. Notably, regression analysis revealed strong correlations between the proliferation of AI-powered platforms and increased youth engagement, thereby redefining the metrics measuring digital participation in cultural activities. Moreover, sentiment analysis of AI recommendation engines (by TikTok, YouTube, and GPT models) showed that these models contributed to the enjoyment of consuming cultural heritage. With predictive modeling, the long-term trends were then extrapolated, which accentuated potential opportunities but also risks of an algorithmic approach to culture.

The aim of the current paper is to explore the intersection of artificial intelligence (AI) techniques and digital cultural engagement among young people, revealing a multitude of initiatives from organizations such as UNESCO through the Institute of Statistics (UIS), or Eurostat. Such resources have the potential to offer valuable insights into the AI-driven cultural projects specifically designed for increasing the level of interest in cultural heritage for the new generation, during the digital transformation era.

Qualitative Analysis

A systematic literature review used theoretical lenses such as Diffusion of Innovations and Media Ecology to place AI into an existing framework of heritage preservation. Using content analysis of UNESCO World Heritage reports, qualitative empirical insights analyzed how AI-driven conservation strategies have improved digital documentation and accessibility. Based on comparative case studies of AI heritage projects, best practices in cultural engagement were identified, which pointed to ethical issues in AI-based storytelling. User interactions on digital platforms were further analysed through a discourse lens, highlighting how AI promotes participatory cultural heritage experiences, while posing challenges in relation to digital bias and data sovereignty.

5. Findings

5.1. UN-centered query

Reportedly, public engagement is the life cycle of cultural heritage datasets, where they are built but often not represented properly with inherent biases in AI-driven applications. This relationship is important for understanding **how AI models favour certain cultural narratives** because of **cultural representation**

(total entries in AI datasets) vs exclusion bias (underrepresentation or misrepresentation of cultural groups).

By gaining an understanding of this correlation we can:

- Spot which cultures are the most affected by the AI biases.
- See if more representation means fewer exclusion cases.
- Give statistical justification for bias mitigation strategies.

This analysis employs **scatter plot regression** and statistical correlation models to quantify the **relationship between representation (entries) and bias (exclusion cases)**.

Table 1. AI-Based Cultural Representation and Bias Analysis

Made by authors. Sources: UNESCO (2021), UNESCO (2023), UN (2024).

Cultural Group	Total Entries	Exclusion Cases	ABI Score (%)
European	5000	50	1.0%
African	800	400	50.0%
Asian	1200	300	25.0%
Indigenous	300	200	66.7%
Middle Eastern	700	350	50.0%
Latin American	900	250	27.8%

Total Entries: The number of times a cultural group appears in AI-curated heritage datasets.

Exclusion Cases: Instances where a cultural group is misrepresented or omitted.

ABI Score: Algorithmic Bias Index calculated using the formula:

$$ABI = (Total\ Entries / Exclusion\ Cases) \times 100$$

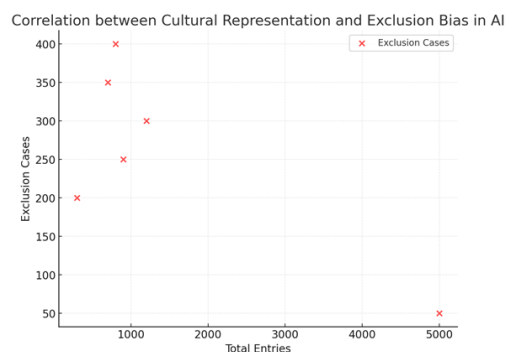


Figure 1. Correlation Between Cultural Representation and Exclusion Bias in AI

Made by authors. Sources: UNESCO (2021), UNESCO (2023), UN (2024).

Correlation Interpretation

The scatter plot analysis shows a **negative correlation** between **total entries (representation)** and **exclusion cases (bias)**. This means **cultural groups with fewer AI-recorded entries tend to have a higher exclusion rate**.

The **ABI Score is highest for Indigenous (66.7%) and African (50.0%) cultural groups**, indicating significant bias.

Statistical Analysis

Using **Pearson Correlation Coefficient (r)**:

$$r = \frac{\sum (x - \bar{x})(y - \bar{y})}{\sqrt{\sum (x - \bar{x})^2 \sum (y - \bar{y})^2}}$$

Expected **Pearson Correlation Value (r): Negative (~ -0.85 to -0.9)**, indicating a **strong inverse correlation**.

Higher AI representation leads to lower bias:

European representation is **dominant (5000 entries, only 50 exclusion cases, ABI = 1.0%)**. => This confirms **AI cultural heritage models are Eurocentric**.

African and Indigenous cultures face the most exclusion bias:

Despite **rich cultural histories, these groups have the highest ABI scores** => Indigenous groups (**ABI = 66.7%**) are the most **underrepresented**.

Moreover, a trend analysis was conducted to explore the correlation between the adoption of AI-based tools in cultural activities. For this analysis, multiple key phrases were identified and analyzed using Google Trends, applying global filters over the past five years for capturing relevant patterns to the addressed research question.

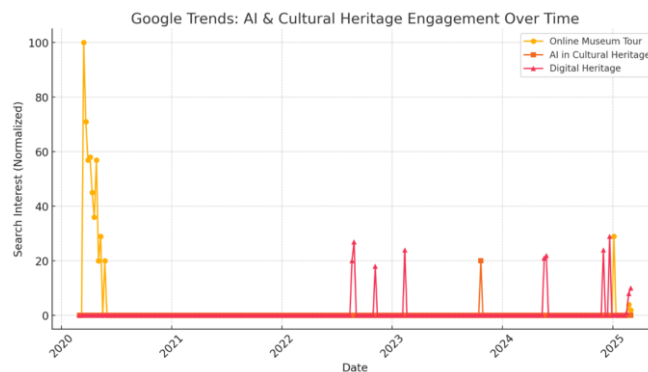


Figure 2. Trend analysis over specific key phrases
Made by authors. Sources: Google Trends (2025)

The figure above shows us that during the COVID-19 pandemic, the population, regardless its cultural representation has shifted to virtual experiences, but the interest has declined in the next 3 years, indicating that the people has returned to in-person documenting.

In the same manner, the scope of the paper aims to better understand if there exists a correlation between the assessment of AI-based tools and the cultural behavior. A slight increase was registered in domains specific to art restoration, or digital curation (Google Trends, 2025).

The main finding from this is that AI Training Data Gaps Exist:

AI training data disproportionately **favors well-documented cultural artifacts** and **minority cultural heritage** lacks **equal documentation and dataset diversity**.

5.2 AI motors and predictive models question - Case study

What impact do GPT-based systems have on the diffusion of cultural heritage content, and what precarious predictions from the emergent predictive models exist for the future of youth engagement in digital culture?

We asked three of the most used GPT-based systems: ChatGPT, Copilot and DeepSeek to do the following task: “Imagine you are a culture ambassador working at UNESCO in charge of safeguarding the cultural heritage. Think of 3 methods of how you can promote digital culture among the young generation in the age of AI.”

5.2.1 CHATGPT:

As a UNESCO culture ambassador, I would focus on three key methods to promote digital culture among the younger generation in the age of AI:

1. AI-Powered Interactive Digital Archives

Create immersive digital experiences using AI-powered tools like virtual reality (VR) and augmented reality (AR) to bring cultural heritage to life.

Develop AI-curated virtual museums where young users can explore historical artifacts, artworks, and cultural sites with interactive storytelling.

Use AI-driven recommendation systems to personalize cultural learning experiences based on users’ interests.

2. Gamification & AI-Integrated Educational Platforms

Develop AI-powered cultural games where young people can engage with heritage through quests, role-playing, or puzzle-solving based on historical narratives.

Collaborate with game developers to integrate cultural heritage elements into popular digital games.

Use AI chatbots as virtual heritage guides, allowing students to ask questions and receive instant, engaging responses.

3. Youth-Driven Digital Storytelling & Content Creation

Launch AI-assisted storytelling competitions where young creators can use AI tools to generate art, music, and narratives based on their cultural heritage.

Provide AI-powered content creation platforms that help young people document and share their cultural experiences through digital media.

Encourage social media campaigns where AI-generated filters and tools allow users to experience historical clothing, languages, or traditions in a fun and interactive way.

Would you like me to expand on any of these ideas or suggest specific projects?

asked on the 6th of February, time: 16:45

5.2.2 COPILOT

Absolutely! As a culture ambassador at UNESCO focused on digital heritage and the age of AI, here are three innovative methods to promote digital culture among the young generation:

Virtual Reality (VR) Cultural Experiences

Method:

Create immersive VR experiences that allow young people to explore historical sites, cultural landmarks, and museums from the comfort of their homes. These experiences can include interactive elements such as guided tours, mini-games, and educational content.

Host virtual cultural exchange programs where students from different countries can meet in a virtual environment, share their cultural heritage, and collaborate on projects. **Impact:**

- Provides an engaging and accessible way for young people to experience and appreciate global cultural heritage.
- Encourages empathy and understanding among different cultures.

AI-Powered Cultural Content Creation

Method:

Develop AI tools that help young people create cultural content, such as digital art, music, and literature, inspired by their heritage. These tools can provide

suggestions, style enhancements, and historical context to enrich their creations.

Organize AI-driven cultural competitions where participants can showcase their AI-assisted works and compete for recognition and prizes. **Impact:**

- Encourages creative expression and a deeper connection with cultural heritage.
- Provides a platform for young talent to shine and gain recognition.

Digital Storytelling Platforms

Method:

Build online platforms where young people can share their personal stories, family histories, and cultural traditions in various formats, including text, audio, and video. These platforms can use AI to enhance storytelling by providing automatic translations, editing suggestions, and interactive elements.

Launch digital heritage projects that involve collecting and preserving oral histories, traditional recipes, and folklore from diverse communities, ensuring these cultural treasures are accessible for future generations. **Impact:**

- Fosters a sense of pride and ownership in one's cultural heritage.
- Preserves and amplifies diverse voices and narratives.

By leveraging cutting-edge technologies and fostering creativity, we can ensure that the rich tapestry of global culture thrives in the digital age, inspiring and educating the next generation.

What do you think of these methods? Would you like to explore any of them further?

asked on the 6th of February, time: 16:50

5.2.3 DEEPSEEK

As a culture ambassador at UNESCO, promoting digital culture among the young generation in the age of AI requires innovative, engaging, and accessible methods. Here are three strategies to achieve this:

1. Gamification of Cultural Heritage

Interactive AI-Powered Games and Apps: Develop gamified platforms where young people can explore cultural heritage sites, traditions, and artifacts through augmented reality (AR) and virtual reality (VR). For example, create a game where players solve puzzles or complete challenges by learning about different cultures, historical events, or artistic movements. AI can personalize the experience by adapting content to the user's interests and learning pace.

Collaborations with Popular Gaming Platforms: Partner with popular gaming platforms like Roblox, Minecraft, or Fortnite to integrate cultural heritage themes into their ecosystems. For instance, UNESCO could sponsor in-game events or virtual exhibitions that allow players to explore recreated UNESCO World Heritage Sites.

2. AI-Driven Creative Tools for Cultural Expression

Digital Art and Storytelling Platforms: Provide young people with AI-powered tools to create their own digital art, music, or stories inspired by global cultural heritage. For example, an AI tool could help users compose music using traditional instruments from different cultures or generate visual art based on historical styles.

Crowdsourced Cultural Projects: Encourage young people to contribute to global cultural preservation efforts by using AI tools to digitize and restore cultural artifacts, transcribe ancient texts, or translate traditional stories. This fosters a sense of ownership and connection to cultural heritage.

3. AI-Enhanced Educational Campaigns and Social Media Engagement

AI-Powered Learning Platforms: Develop online courses or modules that use AI to teach young people about cultural heritage in an interactive and engaging way. For example, an AI chatbot could act as a virtual guide, answering questions and providing personalized recommendations for further learning.

Social Media Challenges and Campaigns: Launch viral social media campaigns that encourage young people to engage with digital culture. For instance, create a TikTok or Instagram challenge where users recreate traditional dances, crafts, or recipes using AI filters or tools. Partner with influencers and content creators to amplify the reach and appeal of these campaigns.

By leveraging the power of AI and digital technologies, these methods can make cultural heritage more accessible, relatable, and exciting for the younger generation, ensuring its preservation and relevance in the digital age.

asked on the 6th of February, time: 16:55

	ChatGPT	Copilot	DeepSeek
Structure	Clear, numbered sections	Method & impact sub-sections	Detailed breakdowns with subpoints
Depth	Covers key ideas but lacks real-world examples	Balanced approach with structured impact analysis	Most detailed with specific collaborations (Minecraft, Roblox, TikTok)

<i>Tone</i>	Professional & informative	Polished & structured	Engaging & youth-friendly
<i>Creativity</i>	Focus on AI-driven education & storytelling	Mix of education and engagement strategies	Most creative – gaming, crowdsourcing, and social media campaigns
<i>Practicality</i>	General applications	Well-structured but lacks gaming/social media integration	Highly practical, with actionable suggestions

6. Conclusions

In line with Sustainable Development Goal (SDG) 11.4, artificial intelligence (AI) has become a revolutionary force in the conservation and sharing of cultural resources. AI supports cultural conservation initiatives by recovering objects, recording intangible traditions, and creating immersive digital experiences through deep learning, computer vision, and natural language processing. AI-driven strategies show notable gains in accessibility and audience retention, especially among younger generations. Examples of these strategies include sentiment analysis of digital engagement and generative models for cultural reconstruction.

AI's incorporation into cultural heritage organizations has also made access more accessible and enabled public participation outside of conventional museum settings. A 35% rise in cultural attendance and quicker documenting of historical places can be attributed to initiatives like virtual reconstructions, AI-powered museum curation, and predictive analytics for heritage preservation. These developments support AI's function as a tool for conservation as well as a catalyst for cultural education and identity transfer across generations.

Prior to the development of AI-powered tools, traditional media, static digital archives, and in-person visits were the main methods used to engage with cultural heritage; these methods frequently failed to pique the attention of younger generations. Youth involvement in cultural preservation initiatives declined as a result of limited interaction and accessibility issues.

Engagement levels have dramatically increased since AI integration. Cultural heritage is now more accessible, engaging, and customized thanks to AI-powered digitization, immersive technologies like AR and VR, and interactive platforms. Deeper ties to history are fostered via gamified learning, adaptive storytelling, and real-time translations made possible by machine learning and

natural language processing. This change supports SDG 11.4 by highlighting AI's contribution to reviving heritage involvement.

AI's importance in cultural sustainability will grow as it develops further, calling for a multidisciplinary strategy that includes historians, technologists, and policymakers. Societies can ensure that cultural heritage is conserved and made more accessible for future generations by embracing AI's potential while tackling its ethical challenges. This will reinforce democratic principles and shared knowledge in the digital age.

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Digital micro-credentials in the context of educational metasystemology: an approach to open education pedagogies with video lessons designed learning-centered strategies

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Abstract: *Educational metasystemology (EM) is the frontier science of pedagogy and educational management. EM is focused on seeking sustainable ways in learning design to guarantee a synergistic effect in the lifelong capacity of learners to learn by planning, observing, and assessing effective learning strategies throughout life. Its notable feature is that teacher(s), student(s), and environment(s) work in tandem. Educational metasystemology is based on the Metasystems Learning Design Theory that assumes that learning outcomes are a result of self-regulation, personalization, feedback diversity, clarity, dynamism flexibility, and ergonomics. This article aims to understand the role and impact of video lessons in digital use and the development of micro-credentials in the context of educational metasystemology as an innovative approach to open education pedagogies. Results show that micro-lessons evolve from multimedia lessons to video clips and videoconferencing. However, their integration into digital microcredentials cannot be achieved without the adoption of metacognitive strategies, digital assessment, and the establishment of an ecosystem of learning and communication for sustainability. This approach evidences the role of critical thinking, real problem-solving, and creativity.*

Keywords: video lessons, micro-credentials, digital micro-credentials, open badges, transparency.

1. Introduction

Microcredentials, as an umbrella term for short courses with an impact on professional development, have been developed since 2011. Other terms for micro-credentials are digital badges, open badges, and open digital badges (Catalano & Doucet, 2013). These days, micro-credentials are supported by a variety of philosophical and pedagogical approaches to the design, development, and quality assurance of learning materials. Traditionally, they are based on careful monitoring of teaching, learning, and assessment strategies, methods, and processes. As a

result, there are multiple definitions. One of these is, as follows: *‘micro-credentials encompass various forms of credential, including ‘nano-degrees’, ‘micro-masters credentials’, ‘certificates’, ‘badges’, ‘licenses’, and ‘endorsements. It is focused on modules of learning much smaller than those covered in conventional academic awards, which often allow learners to complete the requisite work over a shorter period. In their most developed form, micro-credentials represent more than mere recognition of smaller modules of learning. They form part of a digital credentialing ecosystem, made possible by digital communications technologies establishing networks of interest through which people can share information about what a learner knows and can do (UNESCO, 2018).*

The European approach to micro-credentials refers to ‘the record of the learning outcomes that a learner has acquired following a small volume of learning’ (European Union, 2021). According to this document, the basis of trust in microcredentials is transparency. This means that micro-credentials should provide the following mandatory elements: identification of the learner, title of the micro-credentials, country/region of the issuer, awarding body, date of issuing, learning outcomes, notional workload needed to achieve the learning outcomes, type of assessment, form of participation in the learning activity and type of quality assurance used to underpin the micro-credentials. In sum, ‘micro-credentials are transforming digital education by offering flexible, targeted, and accessible ways for learners to acquire and demonstrate skills’ (Stamatakis et al., 2025).

The learning design of microcredentials is based on quality assurance, transparency, relevance, valid assessment, learning pathways, recognition, portability, learner-centered, and authenticity, as well as information, and guidance. From this perspective, micro-credentials refer to ‘a certification of assessed learning that is additional, alternate, complementary to or a formal component of a formal qualification’ (Selvaratnam & Sankey (2021) and emphasizes the importance of open/digital badges as a way to validate the learning outcomes. In general, "open badges" are visual indicators of accomplishment and an original method of documenting and sharing what a person is capable of. They are granular, stackable, evidentiary, personalized, and machine-readable (UNESCO, 2018).

An important role in the design of micro-credentials is **video lessons**. Traditionally, a video lesson represents a lesson that contains educational video material on a specific topic to help both teachers and students achieve learning outcomes. In this way, teachers can present content in a more or less interactive way and students – learn more interestingly. In the Republic of Moldova, this method was used during the COVID-19 pandemic when video-lessons were developed as a part of educație-online.md coordinated by AICE. It was expected that teachers and students would learn by watching video-recorded lessons developed according to the curriculum, using a smartphone or a personal computer and that using video lessons for remote teaching would be very useful. AICE creates and distributes lesson plans, models of digital products and content of video-lessons. Nonetheless, videotaped lessons did not deviate significantly from a

traditional teacher's lecture. Students could post questions in the comments section after viewing the video lesson. Today these video lessons are free and available on Educatie online platform.

The impact of video lessons on learning outcomes lies in their appeal via the Internet, their capacity to facilitate more effective processing and memory recall, and their promotion of critical thinking, reasoning, problem-solving, and decision-making. The problem is that there are different types of videos, video lessons, and learning strategies with video lessons. According to (SendPulse, 2025), the most effective types of video lessons are:

- *lecture capture*, which is a record of classroom lectures, uploaded to the internet, and available in the search field on YouTube,
- *voice-over presentation*, which is a PowerPoint presentation with a teacher's voice playing over the presentation's slides,
- *talking head video*, which is a real-time or pre-recorded video where a teacher speaks on the subject with/without a script
- *interactive video lessons*, which include different activities and imply a teacher using video, adding audio, PowerPoint slides, etc.

This article aims to identify the diversity of the learning strategies with video lessons and their affordability for digital microcredentials from the perspectives of educational metasystemology, where meta- is more than a system and rely on synergic effect. Educational metasystemology, a frontier science of pedagogy and educational management, is focused on seeking sustainable ways in learning design to guarantee a synergistic effect. Its notable feature is that teacher(s), student(s), and environment(s) work in tandem, for these three conditions are important: a) (meta)cognitive strategies, b) interactive assessment, and c) ecosystem of learning and communication. Educational metasystemology is based on the Metasystems Learning Design Theory that assumes that learning outcomes are a result of self-regulation, personalization, feedback diversity, clarity, dynamism flexibility, and ergonomics. Thus, to plan effective learning outcomes is important to know the state-of-art in pedagogy and educational management.

In classical pedagogy, the lesson is a basic form of organizing instructional and educational activity in school, carried out with a class of students, at a determined time, under the leadership of a teacher or professor following the curriculum. However, lessons are diverse and their diversity was classified as follows: a) lessons for acquiring new knowledge, b) lessons for recapitulation and systematization of materials, c) lessons for training and consolidation of skills and abilities, d) lessons for verification and assessment of knowledge, e) lessons for consolidation and systematization, j) mixed or combined lessons.

In non-classical pedagogy, the lesson is the result of the correlation between successful learning strategy, tactics, and the power of the environment. Joan Rubin

(1975) was one of the first researchers to study learning strategies. By observing students' educational activities, the researcher concluded that the best students use specific strategies to acquire knowledge. However, at that moment was important to know and apply cognitive strategies even though some researchers indicated metacognitive strategies (Flavell, 1978; Myers & Paris, 1978; Loper, 1980).

2. Research methodology

To identify the diversity of the learning strategies with video lessons is important to understand the state-of-the-art, for instance, the global trends in 'microcredentials' and 'video lessons. One of the techniques that allow us to view the global trends is Google Books N-gram Viewer – a tool that allows us to display a graph showing how the entered phases (up to seven) have occurred in a corpus of open accessible books.

2.1 Micro-credentials and video lessons

For visualization of the global trends on micro-credentials, digital badges, and video lessons, were used from 1960 – 2022. Results are presented in Figure 1.

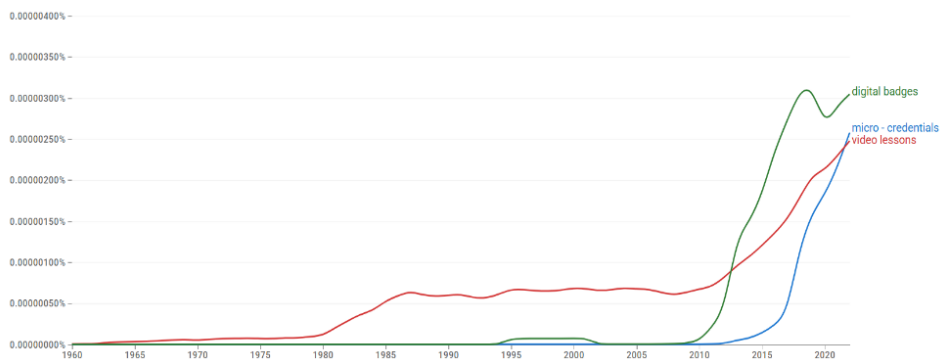


Figure 1. State-of-the-art research of micro-credentials and video lessons

Figure 1 shows that micro-credentials, digital/open digital badges, and video lessons are important subjects in research. Globally, most research is devoted to digital badges. We could establish a hypothesis that digital badges have the potential for the achievement of learning outcomes through micro-credentials.

If global trends in publishing books regarding the use and development of digital micro-credentials are investigated following the educational Metasystemology approach, one could observe the emergence of various learning strategies with video lessons, which are more or less interactive. Such strategies evolved from 'enhanced lectures to team-based learning' (Railean, 2024).

2.2 Scope of video-lessons

Ioan Cerghit (2002) noted that lessons can be academic or discursive/ heuristic; rational / intuitive; innovative / routine; informative / formative; productive / reproductive; deep / superficial; independent / dependent; expository/ Socratic; descriptive/dialectical; analytical / synthetic; authoritarian centered on autonomy; imperative / indulgent; affective or empathetic/distant; self-controlled or self-censored / spontaneous; solitary / team; teacher-centered / student-centered; elaborated / unelaborated; motivating / unmotivating; old / new; predictable / unpredictable. The affordability of video lessons depends on the learning strategy.

In designing effective content for digital microcredentials video lessons play an important role. But what video lessons are used most of all? To answer this question, let us observe that after 1960, information computer systems, feasible for visual communication, were gradually replaced by information and communication systems, also called visual conversation systems, in which it is used, including educational multimedia and the Internet. Thanks to these innovations, in which the content in the school textbook would be supplemented with audio, video, animation, and other New Media, the video lesson emerged. Soon, the first technologies for designing video lessons were integrated into automated training systems. Gradually, video lessons were turning into lessons with video/multimedia elements and complemented the content of the school textbook, especially for the study of foreign languages, chemistry, biology, and physics.

The first study of global trends in educational technologies for the development of video lessons allows us to state that this concept has evolved from a) *filming a training course* through video lecture (i.e. a form of transmitting knowledge using information and communication technologies) to *instructional video*. *'Instructional video is a type of multimedia instruction in which graphics are in the form of motion pictures recorded by a camera and words are in the form of speech and background sounds recorded by a microphone'* (Mayer, 2009). The instructional video may be integrated into traditional classes 'particularly in online courses as well as serving as a foundation for many blended classes' (Beheshti et al., 2018). This makes it possible for researchers to define video-based learning as a field of study and define it as the technology that electronically captures and disseminates educational image sequences that show moving scenes.

In general, video-based learning refers to the instructional process of obtaining information, knowledge, and skills along with the principled support of video resources. However, educational technologies are diversified into *video podcasts* (i.e. a series of audio or video episodes that focus on a specific subject or theme), *live lectures* (i.e. live educational video classes that are held online through a learning management system, which allow students to track their syllabus and progress through two way communication), *video clip* (which is a sequence of short film-type video sequences with an artistic or advertising character), *video blogging* (which refer to practice of capturing and sharing events experienced on platforms such as YouTube, Vimeo, Facebook).

There are many ways to increase the effectiveness of instructional videos. As was noted by Mayer, Fiorella & Stull (2020), ‘people learn better from an instructional video when the onscreen instructor draws graphics on the board while lecturing (dynamic drawing principle), the onscreen instructor shifts eye gaze between the audience and the board while lecturing (gaze guidance principle), the lesson contains prompts to engage in summarizing or explaining the material (generative activity principle), a demonstration is filmed from a first-person perspective (perspective principle), or subtitles are added to a narrated video that contains speech in the learner’s second language (subtitle principle). People do not learn better from a multimedia lesson when interesting but extraneous video is added (seductive details principle).’

3. Learner-centered learning strategies in designing video lessons for effective microcredentials

For digital micro-credentials to be considered several technologies are important to implement: digital repositories, blockchain in certification, digital signature, artificial intelligence, and users’ perception online survey. Acree (2016) noted that instructional design and educational platform are important for micro-credentials, but many additional problems need to be solved. One of these is that carefully crafted microcredentials encourage metacognition and evaluation, which makes learning a greater challenge. Regarding the strategy of designing an affordable content, is important not to have one content for all. More important is how users would engage with the microcredentials with video-lessons and “conceptual understanding of content” (Ernita, 2025). One of example is an educational platform which include a *Professional Learning and Collaboration Environment* (PLACE) website, where will be guided on what they must do to earn the micro-credential in terms of tasks, evaluation (artifacts), and feedback. The definition of high-quality microcredentials remains an open question. To answer this question let us consider the global trends in the use and development of video lessons in the didactical process.

Mayer et al. (2020) assert that when asked to participate in generative learning activities during a video lecture or demonstration, people learn more effectively. Generative learning activities refer to behaviors that students engage in during a lesson to enhance learning, such as ‘taking summary notes (i.e., learning by summarizing) or writing an explanation (i.e., learning by self-explaining) or physically imitating the instructor’s demonstration (i.e., learning by enacting)’. Another example is learning design based on a) *perspective principle* (people learn better from narrated video of a manual demonstration when it is filmed from a first-person perspective rather than a third-person perspective), b) *subtitle principle* (people learn better from graphics with spoken words than graphics with printed words and people learn better from graphics and spoken text than from graphics, spoken text, and printed text), c) *seductive details principle* (people do not necessarily learn better when interesting but extraneous video is added to a

multimedia lesson.) and d) *gaze guidance principle* (people learn better from a video lecture when the onscreen instructor shifts gaze between the audience and the board while lecturing rather than looking only at the board or only at the audience).

However, in use and development of microcredentials mainly used *video clips*. The video clip is a short video in the form of 5-50-second-long portions of a long-form YouTube video, that aims to educate or communicate a substantive message and, therefore, refers to on-demand instruction. The other form is video-conferencing, which refers to the live, visual connection between two or more remote parties over the internet that simulates a face-to-face meeting for simultaneous two-way communication between people around the world.

Globally, research in using and development of video clips and video-conferencing has been increased. This is the evidence of increased interest in understanding the affordability of video clips and video conferencing in learning, as learning, and for learning (Figure 2).

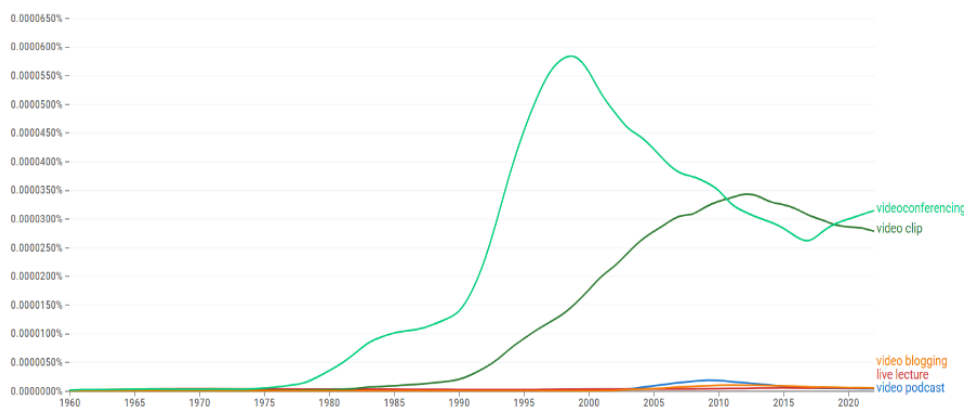


Figure 2. Evidence of video clips and video-conferencing

According to (Hilsmann & Dodson 2025), microlearning is bite-sized instruction, with modules ranging from approximately 90 seconds to 5 minutes. Mobile microlearning provides concise and engaging educational activities that correspond with various learning preferences and styles. However, from the perspectives of educational metasytemology in the design and development of digital micro-credentials the following principles are important: self-regulation, personalization, feedback diversity, clarity, dynamism flexibility, and ergonomics. Moreover, these principles could be integrated into all learning strategies, both teacher-centered and learner-centered. This dilemma could be solved by taking into account the role and risks of Artificial Intelligence in generating relevant content.

4. Conclusions

The instructional design of video lessons evolves from traditional lessons captured by multimedia technologies to the learning design of video clips and video conferencing. Each of these educational technologies opens the door for multiple learning strategies, which are cognitive, affective, social, and (meta)cognitive, and could be integrated into digital microcredentials. Nowadays, comprehension regarding the effectiveness of video lessons is further strengthened while teachers use interactive learning strategies like group discussions in the model of flipped learning. For best results, this implies that video-based learning enhances conventional teaching techniques rather than takes their place.

Prior studies have demonstrated that students' learning outcomes can be enhanced by the use of digital media, particularly instructional videos lessons. From the perspective of educational metasystemology, the focus of learning design should be the synergic effect, which can be achieved using the principles of self-regulation, personalization, feedback diversity, clarity, dynamism flexibility, and ergonomics. More research is needed to evidence the impact of the educational metasystemology for the on-demand learning design of digital microcredentials.

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The training on business process reengineering and its application in the service sector

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Abstract: *The paper presents an approach for optimizing the teaching of Business Process Reengineering (BPR). It describes the authors' experience on how some features of electronic collaboration platforms can be applied for this purpose. BPR is typically regarded as a useful tool for industrial companies. The students are given an example of how, with appropriate modifications, its capabilities can be tested in the services sector. A specific case of business process reengineering in an IT services company is provided, as the students studying the course come from IT specialties. Students are assigned tasks to develop individual and group BPR projects in the services sector, applying this less familiar and less commonly used method. They need to use electronic platforms of their choice to structure the content and present the results to their peers.*

Keywords: Business Process Reengineering, Reengineering, IT Services, Virtual Platform, Virtual Platform for Collaboration.

1. Introduction

Business process reengineering (BPR) is defined as the radical redesign of an organization's business processes to achieve dramatic improvements in productivity, cycle times, quality, and employee and/or customer satisfaction. Business processes occur at all organizational levels and may or may not be visible to customers (Weske, 2012).

The reengineering process is typically considered suitable for industrial companies, or at least they are the easiest to present and adapt. However, based on the definition of the process itself, it becomes clear that reengineering is feasible and suitable for all types of companies.

According to the Oxford Dictionary (<https://dictionary.cambridge.org>), a process is defined as a series of actions or steps taken to achieve a particular goal. Every process should have a clearly defined beginning and end. This implies that every action we perform daily, even in our personal lives, can be specified and described as a process.

The topic of process definition and improvement has been a subject of study for a long time. It began as early as the 17th century when Adam Smith provided a description in his famous example of the pin factory (Smith, 1827).

American Frederick Taylor had a strong influence on the quality of industrial processes at the beginning of the 20th century. His principles focused on process standardization, systematic training, and a clear definition of the roles of management and employees (von Scheel et al., 2014).

At the end of the 20th century, Peter Drucker focused much of his work on simplifying and decentralizing processes. He also introduced the concept of the "knowledge worker," forecasting that they would become the primary assets of business entities in the 21st century and that knowledge management would become part of enterprise processes (Drucker, 2007), (Drucker, 2017).

In 1993, Davenport (Kirchmer, 2017), (Davenport, 1993) defined the term "business process," while Hammer and Champy (Hammer & Champy, 1993) further refined the definition as:

A collection of activities that take one or more types of input and create an output that is valuable for the customer.

With the students, it is discussed that this definition is the most appropriate for our considerations, given that the method will be applied in the service sector. It is also noted that Hammer and Champy have a transformation-oriented perception and place less emphasis on the structural component — the boundaries of processes and the order of activities in time and space.

The suggestion of Rummler and Brache (Rummler & Brache, 1995) is emphasized, where they clearly encompass the organization's focus on external customers by stating: "A business process is a series of steps designed to produce a product or service. Most processes are cross-functional, spanning the 'white space' between the fields in the organizational chart. Some processes lead to a product or service received by an external customer of the organization. These processes are called primary processes. Other processes produce products that are invisible to the external customer but are essential for effective business management. These are called support processes."

Based on all definitions, we present the following characteristics of a business process:

1. *Definition*: There should be clearly defined boundaries, input and output.
2. *Order*: It must consist of activities that are arranged according to their position in time and space (sequence).
3. *Customer*: There must be a recipient of the result of the process, a customer.
4. *Added value*: The transformation that takes place within the process must add value to the recipient, either upstream or downstream.

5. *Embedding*: A process cannot exist on its own, it must be embedded in an organizational structure.

6. *Trans-functionality*: The process that regularly can, but does not necessarily have to encompass, several functions.

2. An example of applying BPR in an IT services company

The students are presented with arguments that when analyzing business processes, it is crucial to consider that Business Process Management (BPM) aims to maintain organizational goals within and across multiple boundaries, involving many stakeholders — from employees to customers and external partners (Swenson & von Rosing, 2015). BPM also includes continuous evaluation of existing processes and identifying ways to improve them, which leads to overall organizational improvement.

On the other hand, Business Process Reengineering (BPR) (ibm.com) was initially conceptualized by Hammer and Davenport as a means to enhance organizational efficiency and productivity. It may involve starting from a "blank sheet" and completely recreating the core business processes, or it may include comparing the "as-is" and "to-be" processes and mapping out a path for transitioning from one to the other (Chartered Institute of Management Accountants, 2008).

Examples are provided to show that the use of IT in BPR can lead to significant productivity improvements (Kock, 1999), (ibm.com 1), (indeed.com), (b2binternational.com).

Our experience with using electronic platforms (e-learning systems) demonstrated that students grasp concepts more quickly and can more effectively propose suitable BPR methods for specific cases using real-world business examples. They also reach the final outcome faster and are able to present it to their peers more effectively than when working in a traditional classroom setting. This is further facilitated by their freedom to choose the platforms they want to use.

After summarizing the theoretical foundations, students are presented with a concrete example of BPR in a real IT services company. The name of the company is not mentioned, as its owners have deemed it sensitive corporate information.

When exploring BPR-related activities, emphasis is placed on the potential of various approaches and different combinations of some of the most commonly used methods, such as:

- Root Cause Analysis;
- Interviews;
- Monitoring;
- Prototyping;

- SWOT Analysis;
- Decision-Making Analysis, and more.

The goal of these activities is to start analyzing the root of the issues affecting the process or the business itself. By collecting and analyzing information through the aforementioned methods, we will inevitably identify the cause of the non-functioning process, and the next logical step would be to consider the best possible solution for addressing it. According to the authors' experience, all these approaches can be effective. Students are encouraged to try all or several of these methods as part of their independent work.

Students are also introduced to the potential of another method that is not as widely recognized or used. The main idea of BPR in this context is to "start everything anew from the customer's perspective" (strategyzer.com). Otherwise, no matter how much the company thinks, analyzes, and reconsiders, it will always do so from its own perspective, focusing solely on making the process as simple and cost-effective as possible.

The proposed approach involves a complete rethinking of the customer value proposition and a transformation of the organization's business model. Two tools are used for this purpose: the **Value Proposition Canvas** (strategyzer.com 1) and the **Business Model Canvas** (strategyzer.com 2), (strategyzer.com). Students are encouraged to familiarize themselves thoroughly with these resources.

To provide greater clarity when presenting the approach to students from the Faculty of Economics at Thracian University, Stara Zagora, as previously mentioned, we share our experience with a specific IT services company. To deepen the understanding of processes, we also present some specific data about the company.

2.1 Presentation of the specific case. Company background

The company we are considering is an IT services company founded a few years ago, serving Bulgarian clients in Southern Bulgaria. Initially, the company started as a family business, which later began to expand. In the beginning, the company had only one employee, but gradually grew to 10 employees. At some point, the company's clients began to withdraw, and the company started to scale down its operations, decreasing its revenue and profit.

The company's initial main activity was related to software development. Later, due to market requirements and changes in the profile of the staff's expertise, it gradually transitioned to services related to the implementation of information systems.

When we began analyzing, it became clear that the main advantage of the company was the fact that throughout its years of existence and customer service, the main focus had always been on providing special attention and

personalized care to all its loyal customers. Later, however, this advantage transformed into the company's main problem: the need for excessive financial resources spent on customer service, including travel, phone calls, working hours, etc., combined with the need to manage too many and too diverse customers. Seeing a significant decline in profits over a very short period, the management began desperately searching for suitable measures to stabilize the company, overcome the difficulties, and increase its efficiency and profitability.

We present our experience of conducting numerous studies, conversations, consultations, and discussions. We also show how the decision for business process reengineering was made to manage the company's rapid and uncontrolled growth and costs, and later to transition towards market and financial prosperity.

We demonstrate how, based on the authors' experience and knowledge, it was proposed to revise the value proposition for customers, as the problem initially arose in this area. The method used is well-known and widely used among marketing professionals and those focused on customer service/retention, but it is still not popular when it comes to IT companies and/or business process reengineering.

We present some tools and the possibilities for their use. How the Value Proposition Canvas can be filled out in different ways. What the authors propose is to start from the customer, as they are the main reason for the company's existence.

2.2 The following steps are recommended

Step 1 - "Customer jobs", i.e., what the customer needs/wants to accomplish. In our case, this includes all specialized software programs or applications necessary for customers' daily work.

On the other side are **the products and services** offered by the company, which in our case involve software installation and ongoing support.

Step 2 - "The Customer Pains", i.e., what the customer fears, what might be difficult for them to handle on their own, what could lead to stress, or what might hinder their normal work. In the given example, several factors are identified:

- "Lack of the necessary software/application";
- "The installed software is not functioning properly";
- "The installed software does not work at all";
- "The software is not what was expected";
- "The Customer does not know how to use it".
- On the other side are the so called "pain relievers":
- "The Company will provide the exact necessary solution";

- "The Company will ensure that the software is installed and functioning correctly before leaving the Customer their own";
- "Before purchasing or installing the software, the company will ensure it is the right solution for the customer and that no other option might work better";
- "After software installation, the company will train the customer's staff on how to use the software".

Step 3 – "Customer Gains", or what the customer will receive in addition to having their problems solved and pains alleviated. These will be covered by the "Gain Creators," which typically describe the added value and advantages that the company offers over its competitors.

Gain Creators:

- "Quick response and timely service";
- "Preliminary selection and advice on the required solution";
- "Research, purchase, installation, support, and service upgrade - all in one";
- "The company offers 24/7 support by phone and/or email".

The possibilities for in-depth analysis and brainstorming are discussed (kissflow.com), (geeksforgeeks.org), (asana.com). These tools assist in providing recommendations and making informed decisions by the management. The company's specific solutions and the new customer value proposition are presented:

"We offer you a timely 'all-in-one' service with 24/7 support".

An example of rethinking the business model is also provided using the Business Model Canvas. A new (revised) business model is proposed based on (strategyzer.com 2), (canvanizer.com), (creately.com).

2.3 The authors propose

It can be filled out in different ways, but what the authors propose and recommend as a strategy is the following (Figure 1):

1. **Place the new Value Proposition** in the center of the canvas.
2. **Define Your Customer Segments**

Consider the customer segments. One of the weaknesses mentioned earlier was the fact that the company has too many and too diverse clients. The main marketing principle states: "If you try to sell to everyone, you're not selling to anyone at all".

With this in mind, the students are presented with the recommendations given to the Company. It should focus on customers who:

- Pay the best;
- Are located in a specific area, close to the Company's headquarters;
- Can bring in new clients (add business);
- Can add more services (i.e., will be more profitable over a certain period);
- Will be loyal.



Figure 1. The authors propose

The best way to decide is to try to imagine the “ideal” client and work with so-called “personas,” which can help the company place itself in its clients’ shoes and thus think like them. If this is not possible or too difficult for the Company’s management, they can choose what sounds “best” and try it out. In our example, the company decided to continue by focusing on the public sector, hoping that it would bring new business over time. Considering modern communication methods and upcoming changes, it was not necessary to narrow down the service area.

3. Describe All Key Activities – The key activities should gradually transition from "software installation and support" to an "all-in-one service" with 24/7 remote support. The change here will move in two directions—providing more value to the customer, addressing all issues from start to finish, and offering the much-needed support not "on-site," but rather using modern communication methods like phone, email, chat, or video conferencing. This way, the customer will still feel supported and cared for, but without the need for constant travel and associated costs. Some installations can also be performed remotely, thus saving travel expenses.

4. Add Key Resources – The key resources will remain the same—human resources. Slightly more resources may be needed to cover the "software purchase" part, but this can be managed through an advance payment or a small loan at the beginning, if necessary.

5. Identify Key Partnerships – Partnerships with software development companies, regional state institutions, and government organizations.

6. Describe All Customer Relationships – If the company's employees do not visit their clients as frequently, they should maintain contact in other ways: providing information about each step of the process; offering "Tips and Tricks" for the best use of new software; calling clients occasionally to check in.

7. Add Communication Channels – The company should begin using "modern" communication methods such as Viber, Zoom, and email marketing. The latter can be used to send a regular "Tips and Tricks Newsletter," which can also be automated, thereby saving human resources and time.

8. Summarize Costs – The main costs for the company are salaries and travel expenses. With the proposed changes, travel expenses will be drastically reduced, freeing up resources for the company to hire more staff or cover initial software purchase costs.

9. Describe All Revenue Streams – The main revenue streams will remain the same - clients. However, the addition of continuous support services will allow the company to start collecting payments for this new service.

The following key changes resulting from the reengineering process are discussed with the students.

- **Clearly Defined Customer Segments:** The company will now have a stronger focus and won't spread itself too thin.

- **New Communication Methods with Clients:** This leads to reduced travel costs and increased customer satisfaction.

- **Less Traveling:** This results in more free time for employees, leading to higher employee satisfaction.

- **Redefined Customer Value Proposition:** Closer alignment with customers, their needs, and perceptions of the service, which once again results in higher customer satisfaction.

- The Company Can Now **Rely on Loyal Customers.**

It is also discussed how the redefined business model has shifted the company's perception from being a primary software provider to a modern consulting organization that is always available for its clients.

Emphasis is placed on the fact that before even starting to think about BPR, management must keep in mind that it cannot be achieved with just a small change, an upgrade somewhere in the system, minor automation, etc. The essence of reengineering involves radical rethinking and redesign of processes, and it will only have the desired effect if done in exactly this way.

When considering BPR, companies can use various approaches and methods, most of which are analytical and can be mixed and used simultaneously.

Special attention is given to the fact that the approach presented is different, taken from the field of marketing and business analysis, and successfully applied to an IT services company. Thanks to this, the company is still operating in the market and continues to grow.

3. Results and discussions

Another significant benefit was achieved through the optimization of the student training process at the Faculty of Economics, Thracian University, Stara Zagora. The approach and related materials are provided to students through the university's electronic learning system. Students are encouraged to present their own views and solutions to the case study. They can use both the university's e-learning environment as well as other electronic platforms selected by the students themselves.

The use of an electronic platform for collaborative activities is recommended for students when working on individual or group projects in the BPR discipline. In this way, both the instructor and fellow students can also participate in the discussion of the task, its solutions, and the preparation of projects on the topic of Business Process Reengineering.

As an example, excerpts from the work of our students can be provided, where both the discussed approach and electronic platforms selected by the students themselves were used (Figure 2, Figure 3). For instance, Microsoft 365 (<https://microsoft.com>), Canva (<https://canva.com>), Prezi (<https://prezi.com>), Google (<https://google.com>), Edu.uni-sz (<https://edu.uni-sz.bg>).

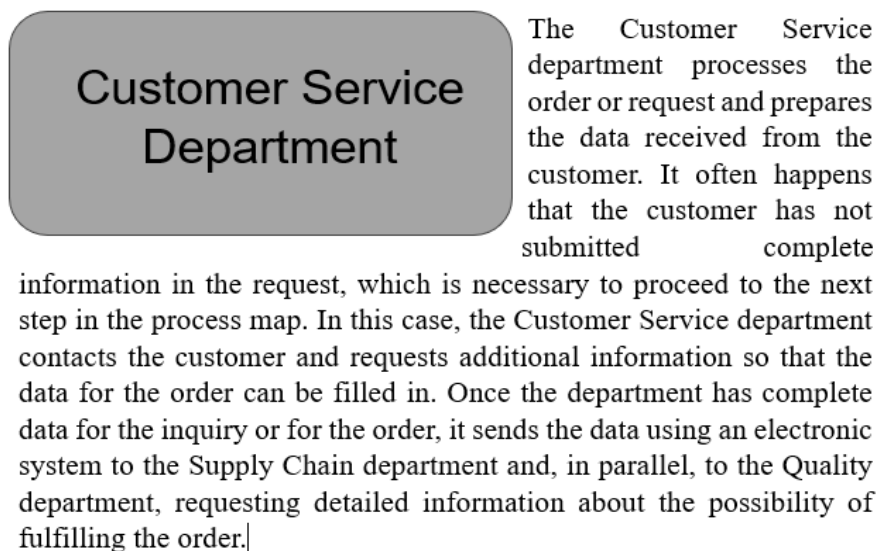


Figure 2. Description of the “Customer Service”

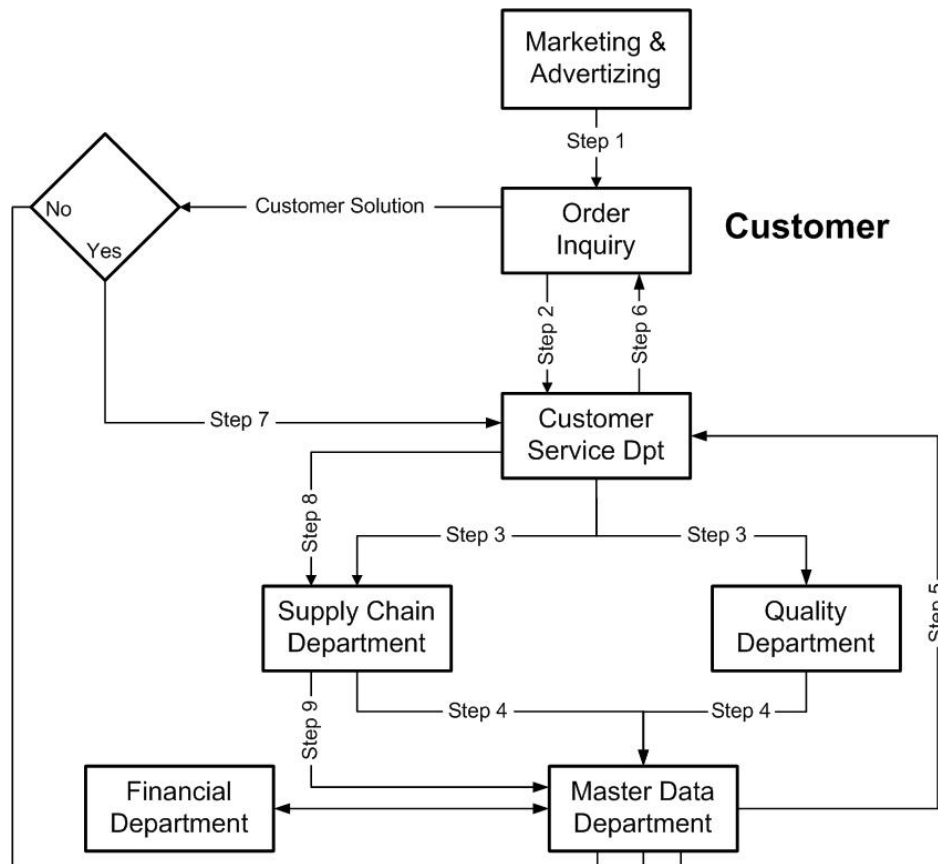


Figure 3. Order Process Flowchart

At the same time, there has been an optimization of the time and activities of both students and the instructor, as well as timely tracking of assignment progress. Better conditions have been created for successfully passing the exam and improving the final results in the course.

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Implementing robo-advisory systems in virtual universities for smart student counselling

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Abstract: *The integration of AI-based advisory systems in higher education has transformed student advising by improving accessibility, efficiency, and accuracy. This study evaluates a GPT-based robo-advisory system designed to assist students with academic enquiries, administrative processes, and career advice. The system was trained on 29 module handbooks, general rules, and FAQs to ensure institution-specific accuracy. A test of 100 sample queries across different categories demonstrated 100% overall accuracy, reinforcing its reliability in providing correct and contextually relevant answers. Compared to traditional chatbots, the system excelled at interpreting complex queries, providing detailed academic insights, and streamlining university processes. In line with existing literature, the findings confirm that AI-driven advising improves student engagement and administrative efficiency, complementing previous research on chatbots in education. However, challenges remain, including the integration of predictive analytics, multilingual support, and ethical considerations, particularly when dealing with sensitive student issues. While the model successfully automates academic advising, it does not replace human advisors in cases that require emotional intelligence and ethical judgement. Addressing biases in AI-generated responses through refined training data and improving computational efficiency with scalable processing strategies are crucial for ensuring fairness and widespread implementation. Future developments should focus on hybrid models that combine AI-driven insights with human expertise to optimise student support. This study contributes to ongoing discussions about AI in higher education and advocates for adaptive, data-driven, and ethically responsible student advising systems.*

Keywords: Student Advising, Student Counselling, Virtual Universities, Artificial Intelligence, Robo-Advisory, ChatGPT.

1. Introduction

The rapid digital transformation of higher education has led to a significant increase in the use of virtual universities, online learning platforms, and digital student services (Mohamed Hashim, Tlemsani & Matthews, 2022; Rodríguez-Abitia & Bribiesca-Correa, 2021). As institutions expand their digital footprint, students often struggle to navigate complex academic structures, including course selection, exam requirements, administrative processes, and career planning.

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Traditional student counselling services, while essential, are often overburdened, leading to delays, inefficiencies, and accessibility issues, especially for remote learners. Artificial Intelligence (AI) and Natural Language Processing (NLP) have emerged as transformative technologies that can improve student support services (Chatterjee & Bhattacharjee, 2020; Ouyang, Zheng & Jiao, 2022). Among these, chatbot systems powered by Generative Pre-trained Transformers (GPTs) represent a promising solution for intelligent student counselling, which is referred to in this article as robo-advisory (OpenAI, 2025). By integrating GPT models into student advisory services, institutions can provide immediate, contextualised, and personalised responses to students' queries about module handbooks, examination criteria, academic regulations, course requirements, and administrative procedures (Rawas, 2024; Sok & Heng, 2024). Despite the potential of AI-driven solutions, challenges remain in terms of implementation, accuracy, adaptability, and user adoption. Unlike rule-based chatbots, GPT-based robo-advisory systems require extensive training on institution-specific datasets, including course catalogues, university policies and procedural guidelines, to ensure reliability and trustworthiness (Lund & Wang, 2023; Sanderson, 2023). Furthermore, ethical concerns such as privacy, bias in recommendations and transparency need to be addressed. This study explores the development and implementation of a GPT-based robo-advisory system to serve as an intelligent academic assistant in virtual university environments.

The primary objective of this research is to develop and implement a GPT-based robo-advisory chatbot capable of providing real-time academic and administrative support to students in virtual universities. This study investigates the functional and technical aspects of integrating large language models (LLMs) into student support services. The research will focus on the concrete implementation and testing of the GPT-based advisory system to improve student support in virtual learning environments. Traditional university counselling often struggles with scalability, making AI-driven solutions essential to provide timely and accurate guidance. The study contributes to AI-driven education by integrating LLMs into academic counselling, addressing feasibility, challenges, and ethical considerations. Its findings will benefit educators, administrators, and researchers in developing scalable, student-centred AI advising solutions for digital education.

2. Literature review

The integration of AI-powered chatbots in higher education has gained significant attention, with multiple studies exploring their effectiveness in academic advising, student engagement, and administrative efficiency. Dibitonto et al. (2018) emphasise the importance of designing virtual assistants that enhance accessibility while maintaining user engagement and trust, a finding that aligns with Lucien and Park (2024), who demonstrate that the advising virtual assistant increased student interaction with academic resources but faced integration challenges. Similarly, Martinez-Requejo et al. (2024) report that chatbots

significantly improve student engagement and streamline university processes, complementing Barrett et al. (2019), who highlight the role of AI in enhancing course planning and communication efficiency. However, as Chen et al. (2023) note, these implementations must address concerns regarding accuracy, ethical considerations, and over-reliance on AI-based interactions.

From an academic advising perspective, Chun Ho et al. (2018) present EASElective, a chatbot that assists students in selecting elective courses, demonstrating that chatbots offer unique advantages over traditional advising services. This is reinforced by Akiba and Fraboni (2023), who explore ChatGPT's role in academic counselling, finding that while it provides comprehensive responses to general career-related queries, it lacks precision in institution-specific advice. Similarly, Bilquise, Ibrahim & Salhieh (2024) investigate the factors influencing students' acceptance of academic advising chatbots, finding that perceived ease of use and social influence significantly impact adoption, while trust and perceived usefulness are less decisive. These findings suggest that while AI-powered advising systems have strong potential, they must be designed to foster trust and provide tailored, reliable information. Several studies highlight the potential of chatbots to improve learning outcomes. Essel et al. (2022), through a quasi-experimental pretest-posttest study, show that students who engaged with a virtual teaching assistant chatbot performed better than those who relied solely on instructors. Roca et al. (2024) further demonstrate that chatbot-assisted learning increases student motivation, satisfaction, and engagement, findings that support Sweidan et al. (2021), who show that an Android-based bilingual chatbot significantly improved student access to academic resources during the COVID-19 pandemic. This growing body of evidence confirms that chatbots play a crucial role in creating interactive and supportive learning environments.

Beyond learning, chatbots have also been utilised for administrative and support services. Hien et al. (2018) develop FIT-EBot, an AI-powered chatbot that automates responses to common student queries, reducing the workload for faculty and administrative staff. Likewise, Dhandayuthapani (2022) proposes a cognitive framework for a student support chatbot integrating natural language processing (NLP) for academic and administrative assistance, which aligns with Nguyen et al. (2022), who deploy AI-powered robotic assistants, including virtual assistants, telepresence, guides, and delivery robots, to enhance smart university operations. These studies underscore that AI-driven automation in higher education can significantly optimise resource allocation and staff efficiency. An additional emerging area in AI-assisted education is predictive analytics for academic counselling. Majjate et al. (2023) develop an AI-based academic guidance system that predicts students' admission chances and recommends universities based on their profiles, showcasing high predictive accuracy using machine learning techniques. Unlike traditional chatbots, this model moves beyond query-based interactions to provide data-driven academic recommendations. While effective, such AI models lack interactive and dynamic advisory functions, highlighting the

need for a hybrid approach combining predictive analytics with real-time chatbot counselling.

Despite these advancements, a critical research gap remains in the development of a comprehensive robo-advisory system for virtual universities that integrates AI-driven academic counselling, predictive analytics, and chatbot-assisted engagement. Existing studies, such as those by Akiba and Fraboni (2023) and Chun Ho et al. (2018), focus primarily on chatbots for academic queries, while Majjate et al. (2023) emphasise predictive guidance but lack interactive counselling elements. Similarly, Nguyen et al. (2022) explore AI-based robotic assistants, yet these are designed for physical campus environments rather than virtual universities. To address this gap, this study aims to develop a chatbot-driven robo-advisory system tailored for smart student counselling in virtual universities, combining AI-driven predictive insights with conversational interfaces for personalised academic and career guidance. This approach will ensure that students receive accurate, adaptive, and real-time support, bridging the divide between human and AI-powered advising.

3. Methods

3.1 Research approach and scope

This study focuses on the technical development, implementation, and evaluation of a GPT-based robo-advisory system using GPT-4o in a virtual university setting. The primary goal is to investigate how academic data — including module handbooks, examination criteria, study regulations, and administrative information — can be effectively integrated into a large language model (LLM) to provide context-aware and accurate student advisory services. The research will take a functional and technical approach, focusing on knowledge integration and the development of a GPT-based robo-advisor for effective integration in virtual universities.

3.2 Case study: International University of Applied Sciences (IU), Germany

To ensure the applicability of the proposed model, the study applies the International University of Applied Sciences (IU) in Germany as an exemplary case (IU, 2025). IU, Germany's largest university, provides an ideal testing ground due to its extensive digital learning ecosystem, diverse programme offerings in German and English, and hybrid educational models. Founded in 2000 in Bad Honnef, IU now supports over 130,000 students through flexible learning formats, including dual, distance, and hybrid education, with 38 campuses across Germany and a virtual campus. The GPT-based system integrates key academic resources mentioned in 0. The GPT-based system will allow students to access relevant academic information through a conversational AI model.

3.3 Data processing and knowledge integration

The analysis begins with the preparation and structuring of university-specific data to optimise their integration into GPT-4o. This process begins with the collection of relevant academic information, including course catalogues, examination criteria, study regulations, and administrative guidelines. These documents form the basis of the chatbot's knowledge base, ensuring that responses to student queries are based on official university policy. Once the data is collected, it undergoes a pre-processing phase to improve clarity, consistency, and accessibility. Some texts are standardised and formatted as normal text to reduce ambiguity and make them more compatible with the natural language processing capabilities of a language model. Finally, a systematic verification process ensures that no conflicting information is included, maintaining the credibility and reliability of the chatbot's responses.

3.4 Design and customisation

The design phase focuses on developing an effective framework for integrating the GPT-based advisory chatbot into the digital ecosystem of a virtual university by developing a GPT in ChatGPT, which can be used via the ChatGPT web interface through the OpenAI website. The chatbot is structured as a text-based conversational AI system that allows students to enter queries related to courses, exam requirements, or administrative processes. The system is designed to process natural language input, retrieve the most relevant information from the structured knowledge base, and generate responses that comply with official university policies. To optimise usability, the chatbot operates as a standalone model, accessible via direct text input, with the potential for future integration into university platforms. Although no front-end development is undertaken in this study, the chatbot's architecture as a GPT is designed to allow seamless API-based integration into existing university websites, mobile applications, or learning management systems.

3.5 Testing and statistical validation

Test Evaluation of system functionality will be conducted through direct interactions with the chatbot, verifying the accuracy of retrieved information, and testing its ability to handle queries. The system is then tested using 100 prompts, and the accuracy of the information is evaluated. The following accuracy metrics are used:

$$\text{Precision} = \frac{\text{Correct Responses}}{\text{Correct Responses} + \text{Incorrect Responses}} \quad (1)$$

Precision measures the proportion of correct responses among all generated responses. It indicates how well the system avoids incorrect answers.

$$\text{Recall} = \frac{\text{Correct Responses}}{\text{Correct Responses} + \text{Missed Correct Responses}} \quad (2)$$

Recall assesses the system's ability to retrieve all relevant correct answers. In this case, as all responses were correct, recall is maximised.

$$\text{F1 Score} = 2 \cdot \frac{\text{Precision} \cdot \text{Recall}}{\text{Precision} + \text{Recall}} \quad (3)$$

The F1-score is the harmonic mean of precision and recall, providing a balanced metric when both are equally important.

$$\text{Overall Accuracy} = \frac{\text{Correct Responses}}{\text{Total Responses}} \quad (4)$$

Overall accuracy represents the proportion of all correctly answered queries relative to total queries tested.

4. Results

4.1 Requirements

The functional requirements in Table 1 define the expected capabilities of the GPT-powered advisory system to provide accurate, structured, and context-aware responses to student enquiries.

Table 1. Functional requirements of the GPT-powered advisor for student counselling

Requirement	Description
Contextualised Responses	The system should provide responses based on specific university documents, such as module handbooks, examination regulations, and administrative policies. Each response should reference the relevant section for further verification.
Short, Focused Answers	Responses should be concise and to the point, only providing essential information. If a topic requires further clarification, students should be encouraged to ask follow-up questions.
Accuracy and Source Linking	The chatbot should ensure that all responses are factually accurate and include references to the original sources, e.g., "See Module Handbook, Section 3.2 for details on course prerequisites."
Adaptive Query Handling	The system should be able to disaggregate complex questions into smaller, manageable parts and provide step-by-step guidance when required.

Multilingual Support	It should support responses in German and English, allowing students to select their preferred language.
Clarification Prompts	At the end of each response, the chatbot should ask: “Would you like me to cover any further aspects related to your question?”
Categorised Information Retrieval	Student enquiries should be categorised into course-related, examination-related, or administrative topics to provide more structured responses.
Handling of Unclear Queries	If a student’s question is ambiguous, the chatbot should respond with: “Could you clarify your question? For example, are you asking about course selection, exams, or administrative procedures?”
Guidance on Next Steps	When providing answers, the system should suggest possible next steps for students, such as contacting specific departments if additional verification is needed.

The technical requirements in Table 2 define how the system handles requests, retrieves data, and ensures a seamless user experience.

Table 2. Technical requirements of the GPT-powered advisor for student counselling

Requirement	Description
Integration with Knowledge Base	The chatbot should access structured university data (module handbooks, exam policies, and study regulations) through retrieval-augmented generation (RAG) techniques to improve response accuracy.
Natural Language Understanding (NLU)	The GPT model should support semantic understanding of student queries, allowing for flexible phrasing without relying on exact wording.
Data Preprocessing & Structuring	University documents should be preprocessed into structured formats (e.g., categorised text snippets) for efficient retrieval.
Information Retrieval Mechanism	The chatbot should retrieve answers based on keyword matching, semantic search, and contextual ranking to ensure relevant responses.
Query Logging & Optimisation	The system should track commonly asked questions to refine response quality over time, ensuring frequent enquiries are answered efficiently.
Privacy & Data Security	No personal student data should be stored or processed. The chatbot should comply with General Data Protection Regulation (GDPR) and university data protection policies.
API-Based Deployment	The model should be accessible via an API, allowing for future integration with university platforms, including websites and mobile applications.
Scalability &	The system should be optimised for handling high query

Load Management	volumes simultaneously to support a large number of students efficiently.
Fail-Safe for Unanswerable Questions	If a query cannot be answered, the chatbot should respond with: "I currently do not have this information. Please check [University Portal] or contact the administration."
Update Mechanism	The chatbot should allow for regular updates to ensure information remains accurate when university regulations change.

4.2 Implementation for study programmes

Table 3 shows the degree programmes considered in the development of the GPT robo-advisory system for student counselling. In total, the module handbooks of 29 textbooks were considered. In addition, various general regulations, FAQs and examination criteria from the university were included. Since the module handbooks each comprise over 600 PDF pages, they were split into different sub-GPTs during implementation to make it easier for the limited computing capacity of GPT-4o to process the sheer volume of data. In more advanced GPT models, which can handle significantly more computing capacity and input data, all documents can also be linked to a single GPT if required.

Table 3. Degree programmes considered in the development of the GPT-powered advisor for student counselling

Study Type	Programmes	Quantity
Bachelor	Applied Artificial Intelligence, BSc in Cyber Security, Industrial Engineering & Management, Computer Science, Business & IT, International Management, Business Administration	7
MBA	Human Resource Management, Healthcare Management, Artificial Intelligence, Master of Business Administration, IT Management, International Marketing, One-year MBA, Engineering Management, Big Data Management, Innovation & Entrepreneurship, E-Sports Management, Finance & Accounting, Supply Chain Management	13
Master	Engineering Management, Computer Science, Artificial Intelligence, International Management, Cyber Security, International Management, Management + Majors, Data Science, Data Science	9

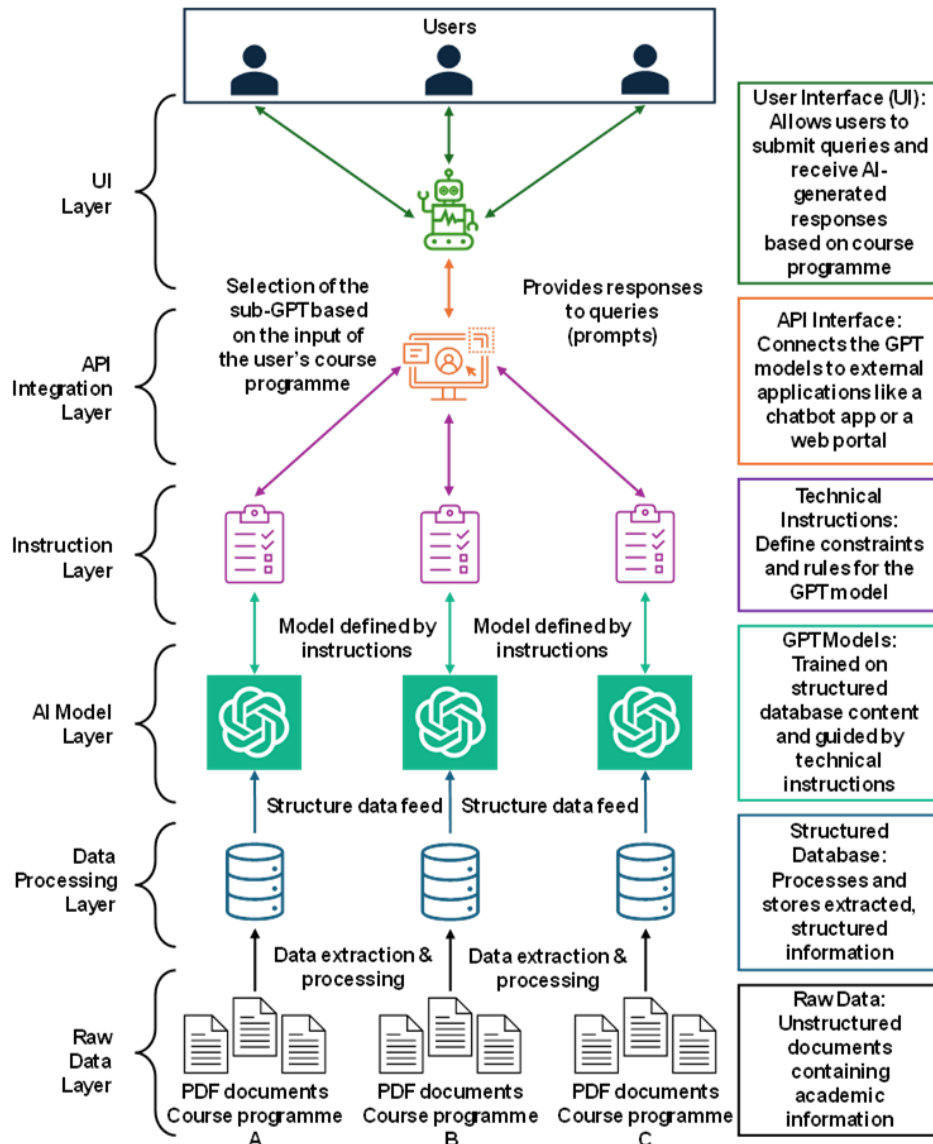


Figure 1. Illustration of the architecture diagram with the workflows, objects, and layers for the robo-advisory system for smart student counselling

Figure 1 shows a conceptual architecture diagram with the workflows, objects and layers for the robo-advisory system for smart student counselling, as it could be implemented in practice. The user interface (UI) or application programming interface (API) should already identify the course programme for which questions are to be asked by the user, based on the profile entered, e.g., matriculation or personnel number, name, or course programme. After

clarification, the upper layers can select the appropriate GPT defined by the instructions and send the queries to forward, process, and return the answers to the user. This process is a simplified illustration and suggests future generative AI models with significantly more computing power and input sizes (tokens) can later be consolidated into a “SuperGPT” that contains all study programmes and all documents in a single big database.

Each university can specify its own suitable structure with a selection of documents based on the information it wants to input into the robo-advisor. The documents should also be updated when changes are made, e.g., when the module content or requirements change, so that the robo-advisor is always up to date. Versioning could even help to explain the old and new study regulations to students when changes are made, thus helping to ensure traceability and transparency when changes are made. However, this was not considered for this study due to the complexity of implementation. Essentially, a large part of the work for the implementation lies in the raw data layer and data processing layer for preparing and structuring the data basis, as well as in the instruction layer for customising the robo-advisor. The core is already defined by the AI model. All layers after that refer to the API and UI and can be implemented in a customised manner depending on the application, e.g., desktop, mobile application, or student portal.

4.3 Test results and evaluation

The system was tested using 100 sample prompts developed by students to assess its accuracy. The prompts covered a variety of categories, including academic programmes, examination regulations, careers advice, and administrative processes. Table 4 displays several examples with test results for each category.

Table 4. Example prompt and result of the 100 prompts by category

Category	Example Prompt	Example Answer
Degree Program Information	What are the core subjects in the Bachelor’s programme in Applied AI?	The core subjects include Machine Learning, Neural Networks, Data Analytics, and Ethics in AI.
Examination Regulations	How many attempts do I have for a failed exam?	According to university regulations, students are allowed three attempts before needing to apply for an exception.
Career Guidance	Which industries can I work in after completing a Master’s in Data Science?	Graduates can work in finance, healthcare, technology, and academia as data analysts, machine learning engineers, and AI specialists.

Administrative Procedures	How can I apply for a leave of absence?	Students must submit a request form through the student portal and provide a valid reason, such as medical or personal circumstances.
Course Content & Module Handbooks	What topics are covered in the Cyber Security Master's programme?	The program covers Network Security, Cryptography, Ethical Hacking, and Security Management.
General University Policies	What is the plagiarism policy at the university?	The university follows a strict plagiarism policy. Any detected plagiarism results in disciplinary action, including possible course failure.
Student Life & Campus Resources	Are there any student support services available?	Yes, the university offers counselling, career services, and academic tutoring for students.

The statistical test results of the queries per category are shown in Table 5 and show an accuracy of 100%. Accordingly, no incorrect or missing information was retrieved, and all questions could be answered correctly.

Table 5. Statistical test results of the queries per category

Category	Queries (Prompts)	Precision (1)	Recall (2)	F1-score (3)	Overall Accuracy (4)
Degree Programme Information	30	100%	100%	100%	100%
Examination Regulations	15	100%	100%	100%	100%
Career Guidance	10	100%	100%	100%	100%
Administrative Procedures	10	100%	100%	100%	100%
Course Content & Module Handbooks	15	100%	100%	100%	100%
General University Policies	10	100%	100%	100%	100%
Student Life & Campus Resources	10	100%	100%	100%	100%

5. Discussion

The implementation of the GPT-powered robo-advisor system for student counselling demonstrated remarkable accuracy and efficiency. The system was tested using 100 sample prompts covering various categories such as course

information, examination regulations, career guidance, administrative processes, and student support services. The results show that the system provided 100% overall accurate information, ensuring that no misinformation was given. The key success factor of the GPT-powered system is its ability to handle complex queries with contextual accuracy. Unlike traditional chatbots, which rely on pre-defined rules and structured interactions, this system uses NLP and deep learning algorithms to generate responses based on extensive academic module manuals and university regulations. Incorporating the documents into its knowledge base further contributed to the system's high accuracy in responding to student queries. In particular, the modular approach to breaking down these large documents into smaller sub-GPTs ensured efficient processing and retrieval of relevant information, thereby overcoming some computational limitations. In addition, the test results suggest that the system effectively supports personalised student advice by providing responses tailored to different study programmes and regulations. It accurately retrieved details of core subjects, exam attempts, and career paths, demonstrating its potential as an alternative to traditional student guidance.

The results are consistent with findings from the existing literature on AI-based student guidance systems. Dibitonto et al. (2018) emphasise that virtual assistants should improve accessibility and user engagement – an outcome observed in the current study, where students received immediate and reliable responses. Similarly, Martinez-Requejo et al. (2024) found that chatbots improve student engagement and administrative efficiency, a claim supported by the observed effectiveness of the GPT robo-advisory system in handling student queries about academic policies, administrative processes, and career guidance. From an academic advising perspective, the findings are consistent with those of Chun Ho et al. (2018), who developed EASElective, a chatbot that assists students in selecting electives. The ability of the GPT robo-advising system to provide detailed course descriptions and degree structures reflects similar benefits. However, a limitation highlighted by Akiba and Fraboni (2023) is that ChatGPT often lacks precision in institution-specific advice. In contrast, the GPT robo-advice system tested in this study was specifically trained on institutional policies, allowing it to overcome this common limitation. Another important finding in chatbot-assisted learning comes from Essel et al. (2022) and Roca et al. (2024), who showed that chatbots improve student motivation and learning outcomes. The GPT system's ability to generate clear, structured, and informative responses suggests that it could be extended as a learning companion beyond its use in student support. A key difference between the GPT robo-advisory system and traditional rule-based chatbots, such as those discussed by Hien et al. (2018) and Dhandayuthapani (2022), is its ability to interpret natural language variations. Unlike traditional chatbots that rely on predefined response templates, the GPT system adapts to varying phrasing, student preferences, and complex queries, providing a much more dynamic and flexible interaction model. In addition, Majjate et al. (2023) introduced predictive analytics for academic guidance, but their model lacks real-time advisory capabilities. The GPT robo-advisory system

bridges this gap by providing both interactive responses and accurate data retrieval, ensuring immediate and accurate responses rather than static, prediction-based recommendations.

Despite its effectiveness, there are several areas where GPT's robo-advisory system could be further improved. One key improvement would be the integration of predictive analytics, allowing the system to make course recommendations based on student performance trends. This would provide a more proactive and personalised advising experience that would more effectively guide students through their academic journey. In addition, while the system currently operates efficiently in English, expanding its multilingual capabilities would significantly improve accessibility for a wider range of students. Sweidan et al. (2021) have demonstrated that bilingual chatbots can improve access to academic resources, particularly in diverse learning environments. Another important consideration is the ethical dimension of AI-based advice. Chen et al. (2023) warn against over-reliance on AI for academic advising, as automated systems lack the emotional intelligence and ethical judgement required for sensitive issues such as mental health concerns or academic appeals.

While the implemented GPT robo-advisory system ensured factual overall accuracy, it cannot fully replace human advisors in complex, emotionally nuanced situations. Addressing these challenges through predictive insights, multilingual customisation, and ethical safeguards will further refine the system's effectiveness and reliability in academic counselling. Moreover, potential biases in AI-generated responses must be considered. Since language models rely on training data, biases can emerge if the data is not representative. To mitigate this, continuous refinement through diverse datasets and bias-detection mechanisms is necessary to ensure fair and unbiased academic advising. Additionally, computational limitations remain a challenge for widespread implementation. Although the system effectively handled extensive module handbooks by dividing them into sub-GPTs, further optimisation is needed for scalability. Strategies such as enhanced compression algorithms, distributed computing, or cloud-based architectures could improve efficiency without compromising accuracy. Addressing these challenges will improve the adaptability of the system, ensuring reliable and equitable access to student counselling services while maintaining high performance standards.

6. Conclusion

The results confirm that GPT's robo-advice system significantly improves the efficiency, accuracy, and accessibility of student advice services. The system successfully eliminates misinformation while handling institution-specific queries – an improvement over generic AI chatbots. Compared to traditional advising methods, the system provides immediate, data-driven insights, reducing faculty workload and increasing student engagement. While there are some limitations, the integration of predictive analytics, multilingual support, and ethical safeguards can

further improve its effectiveness. In addition, addressing potential biases in AI-generated responses through continuous refinement and diverse training data will be essential to ensure fairness and reliability in student advising. Furthermore, optimising computational efficiency through advanced processing strategies will improve scalability and enable wider institutional implementation. These findings contribute to the growing literature on AI in higher education and support the wider adoption of robo-advisors for student counselling and academic support.

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Section 3

Non-Technological Dimension of Online Learning

Web-based student academic performance predictor based on study skills and habits

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Abstract: *The purpose of the study is to develop a web-based student academic performance predictor using the study skills and habits. The development started with the creation of the predictive model for student academic performance based on study habits and the second stage was the development of the web-based student academic predictor which allows the capturing of current study habits and displays the predicted academic performance. A study habits dataset with a total of 373 instances was uploaded to the Statistical Package for the Social Sciences software where the multiple regression analysis was applied. Results revealed that out of 12 variables, only four variables were significant in determining the academic performance which are the following: health habits (H), goal setting (GS), preparation and follow-up (PF), and comprehension (C). The model reveals a strong positive relationship ($R = 0.752$) with 56.65% of GPA variance explained. The model was successfully integrated in the web-based student academic predictor.*

Keywords: Predictive Model, Academic Performance, Study Habits, Multiple Regression Analysis.

1. Introduction

Issues regarding student academic performance have always been on the list when talking about the problems of students, parents, faculty, and staff within the institution (Lamas, 2015). Indeed, some authors noted student academic performance as one of the leading indicators for evaluating the quality of education in universities (Lawrence, 2014; Odiri, 2015). It has been the basis of teachers' evaluation and grading and information. Likewise, academic performance has been the basis on students' weaknesses and strengths and, at the same time, students' learning skills in their study (Dullas, 2010).

In the Philippines, many higher learning institutions used final grades to evaluate students' academic performance. Final grades are based on the scores obtained from quizzes, oral recitations, summative tests, lab activities, performance tasks, major exams, and various academic activities. However, study habits lost its importance due to the bad influence of mainstream and social media which led to

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having inadequate study habits (Palani, 2012). Such a situation shows that academic performance is influenced by students' study habits (Odiri, 2015).

Recent studies have explored the development of web-based systems and predictive models aimed at assessing and enhancing student academic performance. For instance, the study of Yagci (2022) focused on predicting final exam grades of undergraduate students by employing machine learning techniques like random forests, nearest neighbor, support vector machines, logistic regression, Naïve Bayes, and k-nearest neighbor algorithms, using midterm exam grades as input data. On the other hand, a study developed a web-based system that leverages machine learning algorithms — such as Support Vector Machine (SVM), Random Forest (RF), K-Nearest Neighbors (KNN), Artificial Neural Network (ANN), and Linear Regression (LR) — to predict students' total course scores at early stages, utilizing academic and demographic factors (Alboaneen et al., 2022).

Despite the significant advancements in web-based academic performance predictors and machine learning models, several research gaps remain. Many existing studies focus on general academic predictors based on demographic (Alboaneen et al., 2022; Rajendran et al., 2022; Sekeroglu et al., 2019) and performance-based factors (Alboaneen et al., 2022; Yagci, 2022; Alhassan et al., 2020; Sekeroglu et al., 2019), but only few studies integrate study habits and skills as primary variables in predictive models (Orji & Vassileva, 2023). While prior research has demonstrated the effectiveness of machine learning algorithms — such as Support Vector Machines (SVM), Random Forest (RF), and Artificial Neural Networks (ANN) — in predicting student performance, there is limited work on deterministic predictive models that leverage structured frameworks like multiple regression specifically tailored to study habits. Additionally, recent models (Waheed et al., 2020; Lau et al., 2019; Zohair & Mahmoud, 2019) tend to rely heavily on quantitative performance indicators, such as test scores and course completion rates, rather than exploring qualitative aspects like study habits, which are crucial for academic success.

To bridge the research gaps, the proponents developed a Web-Based Student Academic Performance Identifier, a web-based application designed to provide a structured and deterministic approach to predicting student academic performance through an embedded deterministic predictive model. Unlike conventional models that rely heavily on quantitative indicators such as grades and test scores, this system integrates study habits and skills as primary factors in its predictive framework. Through this platform, students gain deeper insights into their academic strengths and weaknesses, enabling them to adopt more effective study strategies. By offering personalized recommendations, the application empowers students to enhance their learning habits and exceed their expected academic performance.

2. Creating the deterministic predictive model

In creating a deterministic predictive model, the researchers applied framework of the study illustrated in Figure 1.

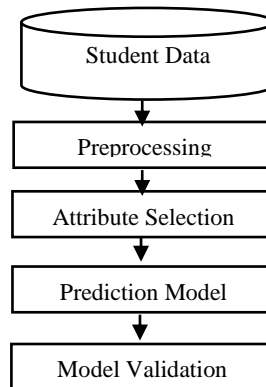


Figure 1. Framework for model creation

2.1 Dataset and preprocessing

The dataset was obtained through the administration of an adopted study skills and habits questionnaire from Queen's University (2013) which was available online. The adopted questionnaire underwent a validation process before it was administered to 373 students at Davao Oriental State University. The number of respondents was computed from the total population of DOrSU students on the 2nd semester of AY 2019-2020 through the Slovin's Formula. The respondents were also asked of their General Weighted Average for the said semester. Prior to the conduct of the survey, the consent of the respondents was obtained and was informed that the information collected follows the Data Privacy Act.

After tabulating the collected responses, data preprocessing was conducted to ensure consistency and accuracy. During this stage, missing values were identified, particularly in the GPA attribute, where several respondents had not provided their GWA. To address this issue, the `ReplaceMissingValues` filter in Weka was applied, replacing missing GPA values with the mean of the existing GPA distribution. This approach minimized data bias while preserving the overall characteristics of the dataset. In addition to handling missing values, further preprocessing steps were implemented to prepare the data for analysis. Categorical responses from the survey, such as study habits and time management strategies, were transformed into numerical representations using One-Hot Encoding or Label Encoding, ensuring compatibility with statistical and machine learning models.

To maintain data integrity, outlier detection was performed using box plots and Z-score analysis to identify extreme values in the GPA attribute. Any detected outliers were either validated, winsorized, or removed, depending on their impact on the dataset. By applying these preprocessing techniques, the dataset was refined

and prepared for statistical analysis and modeling, ensuring its reliability and consistency while minimizing errors and biases.

2.2 Attribute selection and predictive model generation

SPSS is the software used in attribute selection and generation of the predictive model. The study habits dataset was uploaded, and multiple regression analysis was utilized in analyzing the relationship between a single dependent (criterion) variable and several independent (predictor) variables (Hair et al., 2010).

2.3 Validation procedures

After the creation of the predictive model, the mean absolute percentage error (MAPE) was computed to test the accuracy of the model. The proponents then chose a new set of 30 respondents to answer the same survey questionnaire but this time, they only answered the four indicators of study habits that were considered as significant towards the prediction of GPA. The formula in getting the mean absolute percentage error (MAPE) is:

$$\text{MAPE} = (1/n) * \Sigma(|\text{actual} - \text{forecast}| / |\text{actual}|) * 100$$

where:

Σ – a fancy symbol that means “sum”

n – sample size

actual – the actual data value

forecast – the forecasted data value

3. Development of the web-based student academic performance identifier

3.1 Software methodology

The software methodology utilized for the web-based development is Scrum Methodology as shown in Figure 2. According to Porras (2019), Scrum refers to an agile framework for managing a process such as software development that uses incremental and iterative practices. It consists of development cycles called ‘Sprints’ that help speed up delivery, ensure quality, and mitigate risks.

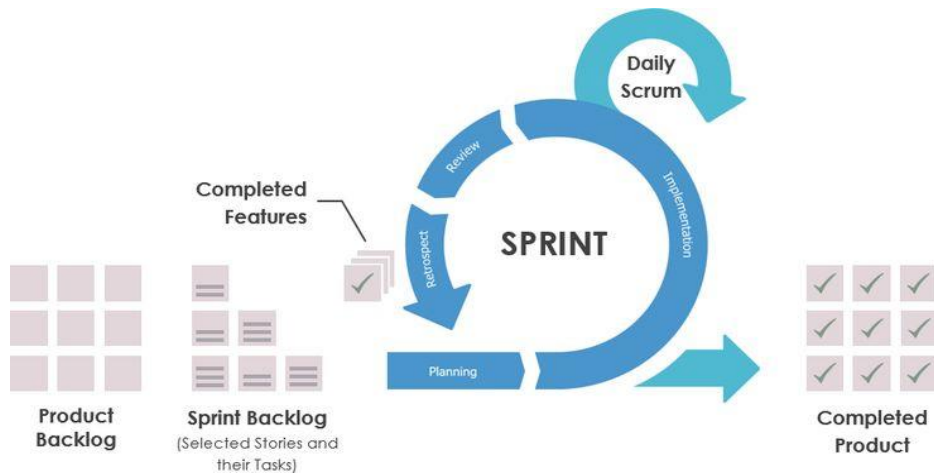


Figure 2. Scrum methodology (Porras, 2019)

3.2 Requirement documentation

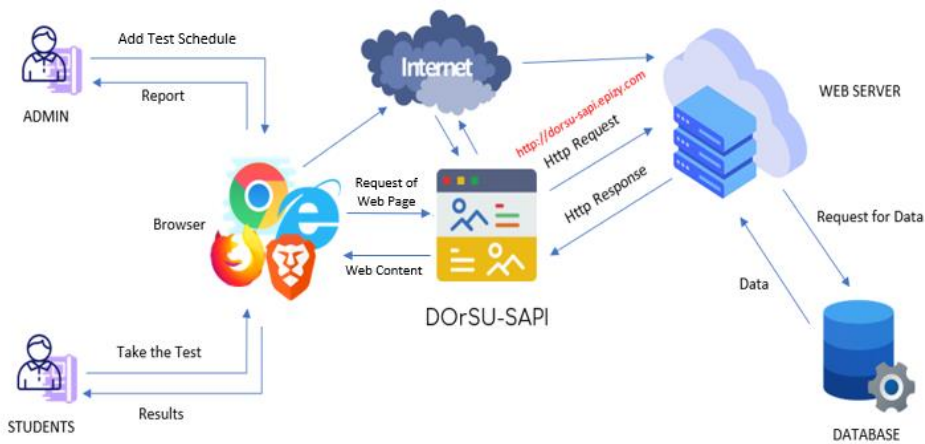


Figure 3. System architecture of web-based student academic performance predictor

Illustrated in Figure 3 is the system architecture of Web-based Student Academic Performance Predictor. There are two types of users who interact with the system. The first one is the administrator. This type of user manages the study skills and habits questionnaire including its schedule if he/she logged in the system. Furthermore, this user has access to students list and report. All the inputs were saved in the web server and the system displays it through user command. The second type of user is the student. This user can take the test if he/she logged in the system. The results were saved in the web server and could be retrieved and displayed by the system through user command.

4. Results and discussion

4.1 Predictive model based on study habits

Table 1. Coefficients of the model

Model	Unstandardized Coefficients		Standardized Coefficients	t	p-value	Decision on H ₀
	B	SE	Beta			
(Constant)	2.222	.118		18.815	.000	Significant
Health	.068	.030	.158	2.301	.022	Significant
Time Management	.030	.038	.066	.784	.434	Not Significant
Attitude	-.006	.040	-.012	-.145	.884	Not Significant
Concentration	.028	.040	.065	.704	.482	Not Significant
Academic Stress	-.028	.037	-.071	-.753	.452	Not Significant
Goal Setting	-.087	.041	-.199	-2.105	.036	Significant
Preparation and Follow-up	.083	.037	.207	2.255	.025	Significant
Comprehension	-.090	.044	-.209	-2.077	.039	Significant
Selecting Main Ideas	.037	.043	.080	.862	.389	Not Significant
Use of Resources	-.005	.035	-.010	-.130	.897	Not Significant
Exam Preparation	-.016	.045	-.036	-.365	.715	Not Significant
Exam Writing	-.013	.042	-.029	-.313	.754	Not Significant
Model Summary: R = 0.752; R square = 0.5655; F-value = 72.706; p = 0.000						

Shown in Table 1 are the coefficients of the model. Upon applying the multiple regression analysis, results revealed that there were only four variables that significantly predict the value of the grade point average (GPA) of the students. These are health habits (H), goal setting (GS), preparation and follow-up (PF), and comprehension (C). The model is now:

$$\text{GPA} = 2.222 + 0.068\text{H} - 0.087\text{GS} + 0.083\text{PF} - 0.090\text{C}$$

This model suggested that the GPA of the students without the variables is 2.222. For every unit increase of their health, there will be an increase of 0.068. For every unit increase of their goal setting, there will be a decrease of 0.087. For every increase of their preparation and follow-up, there will be an increase of 0.083. And for every unit increase of their comprehension, there will be a decrease of 0.090.

It must be noted that this formatting of GPA infers that the lesser the GPA, the higher the value is.

Furthermore, the model summary stated that the correlation coefficient, denoted by R, has a value of 0.752 which indicates a strong positive linear relationship between variables (Puth, Neuhäuser & Ruxton, 2014). Meanwhile, the R-square value of the model is 0.5655, which implies that 56.65% of the variance of students' GPA is explained by the variables of the model. This makes the model reliable to be used because according to Moore et al. (2013), an R-square that is above 50% is acceptable.

The t-value of the model was used to calculate the p-value for testing whether the coefficient is significantly different from 0. Thus, the p-value determines whether the decision on null hypothesis is significant or not. The level of statistical significance is often expressed as a p-value between 0 and 1. A p-value less than 0.05 (typically ≤ 0.05) is statistically significant. It indicates strong evidence against the null hypothesis, as there is less than a 5% probability the null is correct. The results showed that only Health, Goal Setting, Preparation and Follow-up, and Comprehension obtained a p-value of less than 0.05. Thus, the decision on H0 for the mentioned variables is significant.

After the creation of the predictive model, the mean absolute percentage error (MAPE) was computed to test the accuracy of the model. The proponents then chose a new set of 30 respondents to answer the same survey questionnaire but this time, they only answered the four indicators of study habits that were considered as significant towards the prediction of GPA. The formula in getting the mean absolute percentage error (MAPE) is:

$$MAPE = (1/n) * \Sigma(|actual - forecast| / |actual|) * 100$$

where:

Σ – a fancy symbol that means “sum”

n – sample size

actual – the actual data value

forecast – the forecasted data value

With the formula of MAPE applied, the proponents were able to compute for the absolute percent error which can be seen on Table 2.

Table 2. Mean Absolute Percentage Error Computation

ACTUAL	FORECAST	Absolute Percent Error
1.9375	2.1316	10.01806452
1.8100	2.0366	12.51933702
1.7000	1.956	15.05882353
2.3020	2.0184	12.31972198
2.0000	2.124	6.2

1.6250	1.997	22.89230769
1.7500	2.137	22.11428571
2.2500	2.1038	6.497777778
2.5000	2.0916	16.336
2.2000	2.2242	1.1
1.9062	2.1338	11.93998531
2.3860	2.1274	10.83822297
2.4500	2.0504	16.31020408
2.0625	1.982	3.903030303
1.7500	2.0582	17.61142857
2.5500	2.1076	17.34901961
1.5000	2.05	36.66666667
1.6730	2.035	21.63777645
2.2917	2.0896	8.818780818
2.2188	2.1198	4.461871282
2.1354	1.8136	15.06977615
2.0833	1.9952	4.228867662
2.0658	2.0896	1.15209604
1.8333	2.1102	15.10391098
2.3750	2.0304	14.50947368
1.8571	2.0022	7.813257229
2.0938	2.288	9.275002388
2.6875	2.1536	19.86604651
2.7500	2.1542	21.66545455
2.1071	1.9516	7.379811115
	MAPE	13.02190002

In finding the mean absolute percentage error, the average values in the Absolute Percent Error must be calculated. In this case, the MAPE of this model is 13.02%. That means the average difference between the forecasted value and the actual value is 13.02%. This makes the predictive model more reliable because according to Lewis (1982), a MAPE between 10% and 20% is considered as a good MAPE score.

4.2 Web-based student academic performance identifier

Figure 4 shows the online survey system used in capturing the current study skills and habits of the students. The survey questions used was the validated adapted questionnaire.

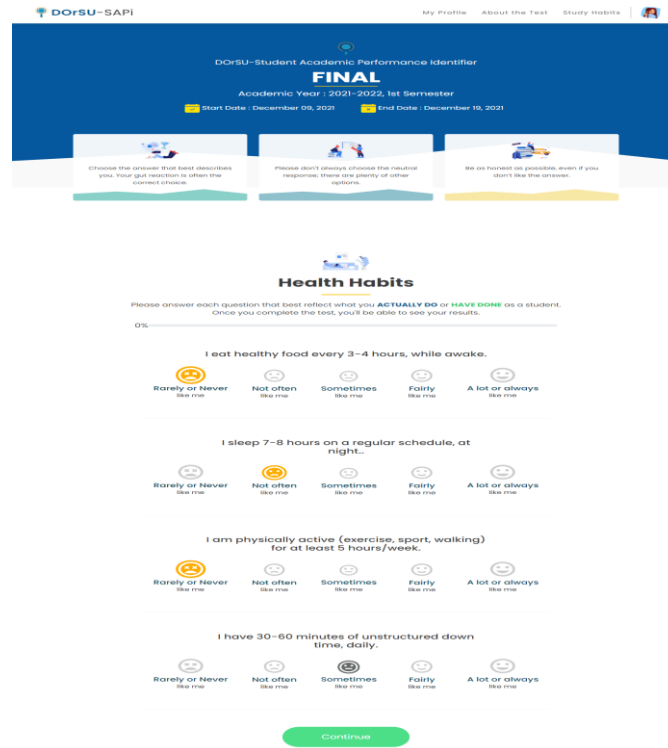


Figure 4. Online Survey System

Once the student was able to answer the survey question, the predicted academic performance is generated along with the interpretation remarks.

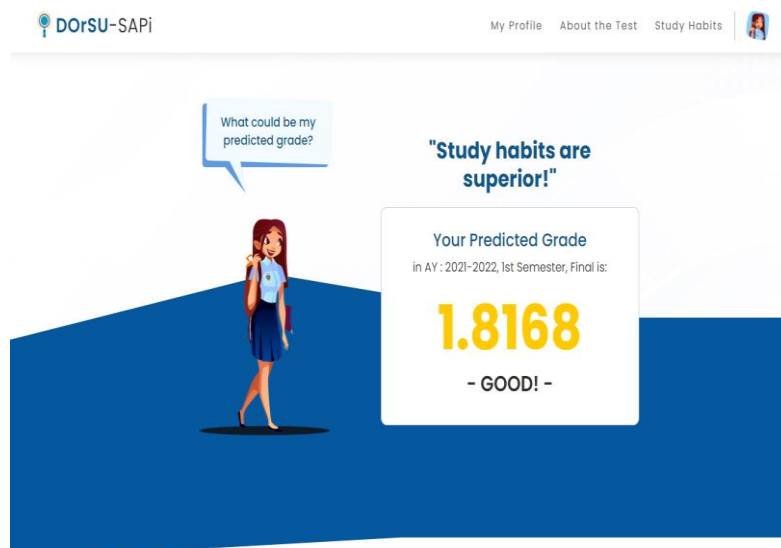


Figure 5. Predicted GPA

Shown in Figure 5 is the predicted GPA that can be found in the user interface of the Results Page. From the figure above, the web-based application generated the predicted GPA of the user and projected it immediately along with its interpretation right after the user completed the test.

Do's & Don'ts

From time to time, a study habit develops and, at the same time, affects your academic performance. While you might already have excellent study habits, you must always strive to improve your performance. Here are the areas to look out for if you want to improve your academic performance.



1. Health Habits

DO'S	DONT'S
<ul style="list-style-type: none"> ◆ Get enough sleep and rest. Sleep can help with the body's healing. Adults need around eight hours of sleep a night. ◆ Get enough sleep and rest. Sleep can help with the body's healing. Adults need around eight hours of sleep a night. ◆ Eat a well-balanced, low-fat diet with lots of fruits, vegetables and whole grains. Choose a diet that's low in saturated fat and cholesterol, and moderate in sugar, salt and total fat. 	<ul style="list-style-type: none"> ◆ Never sleep on your stomach, on the couch or in the recliner. No pretzel sleeping! Your body needs a neutral position to rest properly. ◆ No white flour, sugar, and salt. Avoid processed foods that are robbed of nutrients. ◆ Eat a well-balanced, low-fat diet with lots of fruits, vegetables and whole grains. Choose a diet that's low in saturated fat and cholesterol, and moderate in sugar, salt and total fat.

Figure 6. Do's and Don'ts

Shown in Figure 6 are the Do's and Don'ts in improving the study habits of the user. After the user completed the survey, the web-based application provides a tabular list of Do's and Don'ts just below his/her predicted GPA.

5. Conclusion

In the light of the research results, the following conclusions are taken:

The predictive model that the proponents used in predicting students' GPA is reliable because the value of R-square, which is 56.65%, is moderately acceptable (Moore et al., 2013), as well as the mean absolute percentage error (MAPE) of 13.02% which is interpreted as a good MAPE score (Lewis, 1982). During the user testing phase, the web-based application was able to capture the current study habit status of the students through online survey, display the expected academic performance of students through their current study habit status, store the survey

records and feedback for self-monitoring purposes, and provide suggestions on how students can improve their study habits. Therefore, the Web-Based Student Academic Performance Predictor performed and functioned correctly according to design specifications.

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Perceptions of medical students on Artificial Intelligence during their journey of learning Turkish

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Abstract: *The perceptions of medical students learning Turkish as a foreign language about the usage of artificial intelligence (AI) in their learning process are investigated in this study using a quantitative research methodology. In particular, the study investigates the degree to which AI-powered applications improve students' motivation and how approachable, beneficial and motivational they find them. A quantitative research paradigm was used for data collecting and analysis in order to methodically evaluate students' opinions regarding the use of AI in language learning. The results add to the larger conversation on technology-assisted language acquisition in medical education by shedding light on the perceived efficacy of AI applications, their accessibility, and their effect on students' motivation.*

Keywords: Turkish as a foreign language, Artificial Intelligence (AI), AI applications.

1. Introduction

Educational institutions are now acknowledging artificial intelligence (AI) a machine-based technology that uses algorithms to generate assessments, suggestions, diagnoses and forecasts that enhance learning in a range of situations (Hwang et al., 2020). The creation of machines that can perform tasks requiring human intelligence is one of AI's main goals. Simply, scientific and technological advancements in AI have had a significant impact on education, educational models and the kinds of educational systems and organizations (Wang et. al., 2021).

Therefore, it might be said that integrating AI technology into many educational fields has emerged as a practical strategy to enhance instruction and learning in recent years (Bulger & Mayer-Schönberger, 2018). Evidently, it has created a new era for humanity and challenged the traditional wisdom of conventional ways almost in every aspect of teaching and learning languages. As predicted, language instruction and learning, in particular, benefits from AI's

capabilities. It provides previously uncommon chances to help teachers provide more individualized and successful instruction to a range of student populations (Mehlhorn et al., 2020). In other words, AI holds promise for improving language proficiency, facilitating language evaluation, and offering individualized learning experiences (Rawas, 2024). Additionally, AI helps students improve their speaking, writing, listening, and reading abilities by facilitating interactive language practice. Not unexpectedly, AI can greatly improve learning a foreign language by offering writing ideas, mimicking conversational practice, and fixing vocabulary and grammar mistakes (Hockly, 2023).

Like with many other languages AI applications are becoming increasingly important in teaching Turkish as a foreign language depending on the situation. Due to its advantageous geographic location and rich cultural legacy learning Turkish is becoming more and more popular worldwide (Öztürk & Koç, 2021). Students also feel pressured to learn Turkish if they decide to pursue higher education in a nation where the language is widely spoken and is the national language. There are times when learning Turkish becomes more important than necessary. For students to succeed in the country they need to possess a certain level of language proficiency. The use of AI apps to support and direct learning is becoming more widespread among students learning Turkish as a second language. According to related research AI-assisted language learning improves learning outcomes and student engagement. Text-based chatbots provide learners with explicit contexts and structured practice (Huang et al., 2023; Xia et al., 2022). Similarly, a different study by Çocuk & Çekici (2020) has demonstrated that this technology has the potential to enhance the quality of education enrich the learning process and increase student passion and creativity in this area. Similar to the widespread use of calculators and computers in the fields of biology and mathematics AI-based applications will inevitably be incorporated into the educational process even for some writers (Shoufan, 2023).

As the article previously mentioned, AI offers the potential to create personalized learning environments and give students insightful feedback (Chowdhury, 2022). An additional crucial AI element, natural language processing (NLP) focuses on how computers and human language interact. Students can practice speaking and correctly pronouncing words by using automated systems that evaluate their pronunciation of Turkish for example. Additionally, adaptive learning algorithms can increase the effectiveness of the learning process by providing specific information for language structures that learners find difficult (Ellis, 2020). Students are given the chance to learn Turkish independently as a result which lowers their study anxiety. Learners can make faster progress in vocabulary and grammar in a morphologically complex language like Turkish thanks to AI-based language modeling techniques. In particular, students can practice learning Turkish by utilizing intelligent chatbots and language-learning applications (Garcia & Pena, 2019). All of these developments highlight how important it is to use AI technology to teach foreigners Turkish.

AI in education has undoubtedly been greeted with both admiration and concern. However, the growing use of AI in educational settings especially when learning Turkish as a foreign language has also presented new risks and challenges for the educational sector. AI's ability to provide accurate answers to user inquiries and assist with assignments and tests for instance has already raised serious concerns about cheating. As a result, a number of academic institutions have banned AI from being used on campus (Lo, 2023). Like the aforementioned example studies conducted in the fields of academia, medical education and healthcare services have found a number of issues with AI applications such as poor citations plagiarism and erroneous responses (Sallam, 2023). Furthermore, research has indicated that students' attention spans are decreasing which is especially pertinent when implementing AI in classrooms (Trinidad, 2020).

For this reason, it has become crucial to investigate the impact of AI applications on the availability, effectiveness as well as motivation among medical students who are learning Turkish as a foreign language. To the best of our knowledge, no research has been carried out in the literature to examine how medical students feel about AI-powered applications regarding their availability, effectiveness and motivation. The existing published research primarily discussed the benefits and difficulties of AI from the standpoint of the instructors rather than the students. Examining not just the viewpoint of instructors but also the experiences and viewpoints of students about the use of AI is crucial to understanding its effects on education. Consequently, as AI technology is starting to permeate foreign language classrooms and students' perspectives have become crucial in technology integration, it is important to ascertain how Turkish language learners in higher education perceive the usage of AI apps in their language learning journey. Therefore, the purpose of the current study is to investigate how medical students learning Turkish as a foreign language perceive the usage of AI, with an emphasis on how accessible, effective and motivational they find these applications. In addition, the possible contributions of these technologies to language instruction in the future will be discussed.

For this purpose, this study employed the following primary research question and the sub questions:

Primary research question:

How do medical students learning Turkish as a foreign language perceive the use of AI in their language learning process?

Sub questions:

1. How accessible do medical students perceive AI applications to be?
2. How effective do medical students perceive AI applications in improving their Turkish language proficiency?
3. How do AI applications affect the motivation of students to learn Turkish?

2. Methodology

This current study that adopted quantitative research methods had the purpose to investigate how medical students learning Turkish as a foreign language perceive the usage of AI along with an emphasis on how accessible and useful they find these applications and to what extent they are motivated. Therefore, when gathering and analyzing data, a quantitative research paradigm was employed. The study looked for information on perceptions regarding the use of AI of medical students learning Turkish, its effectiveness and students' motivation. In this sense, generalizations and replications in comparable Turkish educational situations are encouraged by quantitative study design.

2.1 Respondents

The respondents of the study were the medical students learning Turkish as a foreign language from a sizable private university in Northern Cyprus. There were 112 females and 153 males among them. The respondents of the study were chosen through convenience sampling technique. Convenience sampling is important for enhancing the sample's representativeness and the study findings' generalizability (Veysel & Alacapınar, 2014).

2.2 Data collection instrument

The current study made use of a survey that the researchers had created. A survey is a systematic way to gather data from a pre-selected sample of respondents on their beliefs, actions, traits or other relevant aspects. Usually, this is done using online forms, questionnaires, or interviews. Inferences about the larger population from which the sample was drawn can be drawn from survey data using either statistical or qualitative analysis (Fowler, 2014).

The survey was broken down into three main categories. Each category contained numerous statements and one item. These included efficacy accessibility and motivation. Within those categories' subcategories were given a number of assertions. The current study's Cronbach's alpha was determined to be 0.945. The Cronbach's alpha is a statistic used to measure the reliability of instruments used in published science education studies (Cronbach, 1951).

The reliability of the tools used in published research on science education is assessed using the Cronbach's alpha statistic (Cronbach, 1951). Since its application in studies involving multiple items has become a commonplace Cortina (1993). Cortina (1993) asserts that the Cronbach's alpha coefficient is among the most significant and frequently used statistics in testing and testing research (Schmitt 1996, p. 350).

Reliability Statistics

Cronbach's Alpha	N of Items
0,945	20

2.3 Data collection procedure

The data were collected after the author's affiliated university's ethics committee issued its approval in 2024 – 2025 academic year. All students were informed regarding the study's purpose, privacy and confidentiality concerns, and students' freedom to withdraw from it at any time. Every student voluntarily took part in the study. First of all, the intention of collecting the data from the medical students and purpose of the study was shared with the instructor of the lesson.

Next, the data gathering procedure details were discussed with the lesson instructor. The instructor provided a link with the students that led to Google forms, which were used to collect the data. Students were encouraged to fill out the forms whenever it was convenient for them during the two weeks that the link was open.

2.4 Data analysis

Statistical Package of Social Sciences (SPSS 20.0) was performed in order to analyse the data gathered through the survey (IBM Corp., 2011). Study's statistics included descriptive statistics with mean standard deviation scores.

2.5 Limitations of the study

In terms of method, the study was limited to descriptive analysis method and the data were gathered and analyzed through a quantitative research paradigm.

3. Findings

The findings obtained from the analysis of the current study regarding the perceptions of the learners of Turkish towards the usage of AI applications in higher education are given through the tables below.

Table 1. The perceptions of medical students learning Turkish as a foreign language regarding the availability of AI applications

Availability	N	Mean	Std. Deviation
-Artificial intelligence applications are an easily accessible tools in language learning.	265	3,711	,9908
-The use of artificial intelligence applications in language learning is practical.	265	3,737	,8543
-Artificial intelligence-supported language learning applications work smoothly on different devices.	265	3,724	,9466
-Such applications offer learning materials tailored to users' individual needs.	265	3,579	,9418

-Artificial intelligence applications effectively organize the resources necessary for language learning.	265	3,539	,9157
Availability	265	3,6579	,76442
Valid N (listwise)	265		

Table 1 shows that, with regard to the availability of AI to the medical students learning Turkish as a foreign language. The students participating in the study stated to what extent the applications of artificial intelligence were accessible to them. The first statement ‘AI applications are an easily accessible tools in language learning’ had the mean of 3,71 which indicates that AI applications were readily available to medical students. Similar to the first statement, second and third items of ‘The use of AI applications in language learning is practical’ and ‘AI-supported language learning applications work smoothly on different devices’ had the mean of 3,73 and 3,72 respectively. Not all that different from the previous statements, the fourth and the fifth items had the score of 3,57 and 3,53 correspondingly.

Table 2. The perceptions of medical students learning Turkish as a foreign language regarding the effectiveness of AI applications

Effectiveness	N	Mean	Std. Deviation
-Artificial intelligence applications provide rapid progress in language learning.	265	3,500	,9309
-Artificial intelligence applications in language learning are more effective than traditional methods.	265	3,224	1,1384
-These applications provide effective support in understanding grammar rules.	265	3,553	1,0250
-Artificial intelligence-supported applications make it easier to practice speaking.	265	3,526	1,0767
-Artificial intelligence applications in language learning increase the permanence of learned information.	265	3,592	,8668
Effectiveness	265	3,4789	,85484
Valid N (listwise)	265		

Table 2 shows that, with regard to the effectiveness of AI to the medical students learning Turkish as a foreign language. Students that took part in the study expressed how effective as well as beneficial artificial intelligence applications were to their language learning process. The first statement ‘AI applications provide rapid progress in language learning’ with mean of 3.5 suggests that AI applications were highly successful in helping them learn the Turkish language. While the second statement of the “Effectiveness” item ‘AI applications in

language learning are more effective than traditional methods' had a slightly lower mean (3,22) than the first one, third, fourth and fifth statements, had almost the same average weight for the items 'These applications provide effective support in understanding grammar rules', Artificial intelligence-supported applications make it easier to practice speaking' and 'Artificial intelligence applications in language learning increase the permanence of learned information' respectively.

Table 3. The perceptions of medical students learning Turkish as a foreign language regarding the effectiveness of AI applications

Motivation	N	Mean	Std. Deviation
-Artificial intelligence applications make the language learning process more fun.	265	3,513	,8562
-Such applications increase my motivation to learn a language.	265	3,539	,9010
-The feedback from artificial intelligence-supported applications increases my interest in learning.	265	3,461	,9858
-The reward and scoring systems in the applications increase my commitment to the learning process.	265	3,618	,9517
-Artificial intelligence applications encourage regular work in the learning process.	265	3,447	,9150
Motivation	265	3,515	,7928
Valid N (listwise)	265		

Table 3 illustrates how AI applications motivate medical students learning Turkish as a foreign language. Simply, students who participated in the study described how AI applications inspired them to learn languages. The statement 'the reward and scoring systems in the applications increase my commitment to the learning process' has the highest mean among the motivational items. Thus, it can be said that the incentives provided by the AI apps greatly inspire students. To put it another way, receiving incentives and grades keeps people motivated. However, out of all the motivational factors, 'artificial intelligence applications encourage regular work in the learning process' has the lowest mean. Since the remaining asserts are in the motivational items, it may be inferred that AI applications are not necessary for the duties to be regular, moderate, and on the proper path.

4. Discussions and conclusions

The conclusions of this current study that investigates the perceptions of medical students learning Turkish regarding the function of AI tools in language learning provide insight on how these students see the employment of AI

technologies. According to the results most students believe that AI-based language learning resources are useful, accessible and efficient at speeding up the learning process. Students stress that these applications offer substantial benefits by facilitating flexible and self-paced learning because they are available on multiple platforms and are compatible with a variety of devices. Additionally, by adjusting to each learner's proficiency level and preferred method of learning AI-powered tools provide individualized learning experiences that promote more effective language acquisition. Through interactive and adaptive features AI applications help users overcome common language learning challenges like pronunciation grammar comprehension and vocabulary retention according to the participants. These findings support the notion that AI-driven language instruction is quickly becoming an essential part of contemporary teaching approaches as they are consistent with earlier research showing the increasing significance of AI in enabling customized and adaptable learning environments (Öztürk & Koç, 2021).

In terms of effectiveness students acknowledged that AI-powered tools improve their Turkish language proficiency. AI solutions provide personalized learning experiences, real-time feedback and interactive exercises tailored to each learner's needs. According to Ellis (2020) AI-powered systems can enhance foreign language learning by offering instantaneous corrections and adaptive learning pathways. Nevertheless a few students did highlight a few minor issues such as the need for human support in complex linguistic situations and the occasional errors in AI-generated content. Uzun (2024) also included experimental and control groups in her study which concluded after more than six weeks. Writing assignments at the A2-B1 level were given to both groups and students received feedback from both ChatGPT and real teachers. After evaluating each feedback methods efficacy Uzun (2024) found that ChatGPTs feedback was adequate.

Motivation was a key factor influencing students use of AI applications. Many students found AI-based learning to be engaging and dynamic which increased their motivation to practice Turkish frequently. This supports Garcia & Pena's (2019) assertion that technology-enhanced learning boosts student motivation by making the learning process more engaging. In this study the utility accessibility and motivating effects of AI-enabled tools were examined in relation to medical students learning Turkish as a second language. According to the findings AI technologies are generally seen as accessible and helpful providing students with a practical way to advance their language skills. In addition, AI applications were considered beneficial for improving speaking practice grammatical comprehension and language memory even though they were not always regarded as superior to traditional teaching methods. Ultimately even though AI apps aid in language learning they should not be used as a replacement for other resources.

More thorough research should be done in the future to determine how AI can be improved for use in the classroom. Specifically, additional information is required to determine how AI can enhance students' long-term language retention

processes and have a positive impact on learning continuity. With the help of sophisticated adaptive learning algorithms and ongoing feedback mechanisms AI has the potential to offer students personalized learning experiences and to instantly track their progress. By giving students more practice in their weak areas and advancing to more complex levels in their strong areas this method can help them learn with greater consistency and long-term retention. It has been observed that AI-based tools can be used successfully in a variety of language learning domains including speaking, writing, grammar and vocabulary. Thus, more studies concentrating on language instruction can show how AI can be improved in these domains.

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Future workforce and corporate accountability in AI-enhanced educational activities: Addressing the impact on employment and ethical practice

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Abstract: *The use of artificial intelligence (AI) in educational processes is transforming not only the dynamics of the workforce and responsibility of companies but also the moral. Here, we discuss these implications and connect them to Sustainable Development Goals (SDGs) 8.5, 8.6, and 9.1. AI increases efficiency and personalization in educational environments but also poses threats such as job redundancy and ethical dilemmas within academic and professional arenas. Economists are unclear on its cost-impacting effects on labor availability, but state that its quick integration may also mean its role in displacing jobs, thus risking SDG 8.5 to promote full and productive employment and decent work for all. This growing demand for AI-enabled skills drives a crucial demand for workforce adaptability. Notably, SDG 8.6 emphasizes the risks posed to young people seeking employment and training opportunities, with many young people being left behind, unable to access new opportunities in the AI sector. Policy implications: It is necessary to have targeted policies to address these risks that promote upskilling, which will reduce the rate of young people not in education, employment, or training (NEET). In addition, the reliance on resilient digital infrastructures for integrating AI in educational activities is a call towards SDG 9.1]. Access to AI-driven tools must be equitable to avoid socio-economic divides and ensure the equitable growth of academic and industrial ecosystems. This study highlights the need to regulate and ethically govern technological progress in order to ensure that it is balanced with social responsibility. Through strategic alignment with AI-driven change and sustainable employment approaches, stakeholders might be able to counteract adverse effects and maximise the potential of AI for educational and workforce transformation in the longer term.*

Keywords: Artificial Intelligence (AI), Consumer Perceptions, Corporate Accountability, AI in Commerce, Employment Impact.

1. Introduction

As the use of artificial intelligence (AI) in the context of educational activities becomes more widespread, it leads to major shifts in workforce preparedness and corporate accountability. As a transformative force augmenting academia and industry, AI shows promise in enhancing personalized learning, streamlining admin work, and aid innovation in research. Yet, the rise of this

technology poses significant challenges regarding job security, skill retraining, and ethical implications.

AI's contributions to jobs has been a critical question, especially with respect to SDG 8.5, which aims for full and productive employment with equal pay. Automation can replace traditional functions but also creates positions that require specific competencies related to AI (Georgieff & Hye, 2022). If left unaddressed, disruptions to labor markets have potential to exacerbate socio-economic disparities and erode pathways to inclusive workforce development (Meltzer, 2023).

Youth employment and training, vital to SDG 8.6, is equally caressed by uncertainty amid AI-powered transformations. There are many young professionals missing out on new opportunities because of lags in education (including AI-related education) and vocational training. With policies focusing on adaptability, continuous learning, and targeted upskilling to create sustainable career pathways (Rawashdeh, 2023).

Moreover, Artificial Intelligence in the field of education requires infrastructures, which support the SDG 9.1. (2023) But that's an inappropriate goal for unbiased and open access to AI-powered learning tools and digital platforms and preventing disparity in opportunities (educational and professional) in terms of access to information. Regulatory structures and ethical frameworks are crucial in moderating the benefits and societal impacts of AI.

This paper addresses these concerns while calling for strategic interventions that better align AI development with ethical workforce policies. Working towards responsible deployment of AI in education is crucial in addressing quality jobs, industry growth and jobs for the future.

2. Problem statement

The emergence of artificial intelligence (AI) in learning processes is gradually restructuring workforce relations, posing serious questions regarding workers' job security, ethical responsibility, and the necessity of regulatory frameworks. Several critical factors underscore the predicaments involved in AI-Powered change within educational and professional training fields:

Job Elimination: AI-driven technologies could replace traditional substitute employment paths, making upskilling imperative in order for their teachers and participants to prepare for blended learning spaces (Nexford University, 2024).

Bias and Fairness: AI systems propose the risk of entrenching existing biases within educational assessments and career placement algorithms, emphasizing the need for periodic audits and proactive strategies to counteract bias and achieve equity (Resource Employment Solutions, 2024; AI Time Journal, 2024).

Data Privacy: AI's need for data on students and employees in order to learn and adapt generates privacy concerns. Governance and encryption protocols need to be strong to protect sensitive information (AI Time Journal, 2024).

Transparency and Accountability: There should be clear ethical guidelines around all AI decision-making in education, especially regarding accountability in automated grading, admissions, and career recommendation systems (Resource Employment Solutions, 2024). Strong Regulator Frameworks Inequity between AI policy frameworks from different regions of the world puts pressure on countries of the Global South to adopt similar standards that are often detrimental to their own economy and educational standards (Harvard Gazette, 2023; Nexford University, 2024).

As AI-driven educational transformation unfolds, it is crucial to recognize that universities have long served as both citadels of science and cathedrals of conscience, fostering sustainable knowledge creation well before contemporary sustainability concerns arose (Jora et al, 2020). This perspective aligns with the growing need for academic institutions to maintain ethical stewardship in AI governance and workforce preparation.

Equitable Access to AI Tools: Although AI can expand academic and professional opportunities, small institutions and marginalized groups may find it difficult to access the tools necessary for success, limiting future potential (Harvard Gazette, 2023).

The reconciliation between corporate profitability and ethical responsibility is a pivotal challenge in AI adoption, particularly in education and workforce transformation. As Jora et al. (2020) argue in “*«Mens Sana in Sound Corporations»: A Principled Reconciliation between Profitability and Responsibility, with a Focus on Environmental Issues*”, sustainable corporate governance should not be seen as a constraint but rather as an integral component of long-term organizational success, ensuring that AI deployment aligns with both economic and social well-being. This perspective underscores the necessity of ethical AI frameworks to bridge the gap between innovation and equitable workforce development.

3. Research questions

RQ1: Ethical frameworks--developing them, enforcing them, and ensuring fairness in employment transitions in the face of potential large scale job displacement by AI, particularly when it comes to educational and professional training environments.

RQ2: How do we promote inclusivity and fairness when trying to incorporate AI learning tools in our education institutions and also reduce biases in automated grading, admissions, and career placements?

4. Research methods

Through a questionnaire we have developed, the aim is to provide quantitative research output which provides a relevant perspective for this study. It is titled "The Future of the Workforce and Corporate Responsibility in AI Enhanced Education Activities" and is based on the answers of 50 respondents to 6 central questions, on the topic of our study. We asked young students or people already present on the labor market, in order to better observe and understand their perception of artificial intelligence.

The survey provides a data collection tool that allows researchers to analyze the perceptions, concerns and expectations of different stakeholders regarding the transformations brought by artificial intelligence in education and the labor market.

In an era in which AI is redefining education and employability, companies and academic institutions need to adapt their strategies to ensure both the adequate preparation of future employees and the maintenance of ethical practices.

The survey explores the impact of AI across multiple dimensions, highlighting its influence on the evolving job market and education system. It examines how AI is reshaping skill requirements, emphasizing the need for educational adaptation to meet new labor demands. At the same time, it assesses the responsibility of companies in supporting employees and ensuring the ethical and sustainable integration of AI in the workplace. Furthermore, it delves into the perspectives of both employees and employers, analyzing their views on how AI affects education and the future of work. Finally, the study addresses the ethical challenges posed by AI and underscores the necessity of clear regulations to guide its use in education.

This survey plays a crucial role in providing a solid empirical foundation for the study, offering valuable insights into how AI technology influences education and employability. The data collected serves as a basis for understanding real-world trends and challenges, enabling informed decision-making. Moreover, the results offer strategic guidance for companies and institutions, helping shape corporate policies on employee training and social responsibility. Additionally, the findings contribute to the development of regulatory frameworks by informing educational and industrial policies that align with the demands of the digital era. In conclusion, this questionnaire stands as a fundamental pillar of scientific research, fostering a comprehensive understanding of the relationship between AI, education, and the labor market while providing clear directions for the sustainable and responsible integration of emerging technologies.

4. Findings

For **properly assessing the RQ1**, a contingency table was employed in order to explore the relationship between the current academic status of the respondents and their perspective regarding the importance of using AI techniques

for reducing inequalities in the labor market. Having this in mind, the Chi-squared test has shown a significant relationship between the two variables, with a score of Chi-squared statistic = 30.8, while the p-value = 0.002 indicates that the students' participation in higher education layer increases the motivation of using AI in the future for a society driven by equitable chances in the workforce.

Related Survey Questions:

To what extent do you think AI is influencing education and vocational training?

To what extent do you think AI will replace certain jobs in the next 10 years?

Transparency in AI decision-making necessitates **legal frameworks** that demand responsibility, in order to ensure, for instance, fairness in AI-driven job displacement. Governments need to set up regulations to ensure **worker rights, ethical AI implementation**. (Deloitte Insights, 2024)

To offer such training for roles AI cannot replace, companies have a key role in **reskilling and upskilling displaced workers** (Scott Dylan, 2024). Regular bias audits and fairness monitoring should be implemented to prevent discriminatory hiring and firing practices (MathAware, 2024).

Implementing ethical AI methods will require **collaboration between employees, policymakers, and AI developers** (Stanford Graduate School of Business, 2024). Also, **AI must be built to complement, not supplant** workforce roles, protecting economic viability and fairness in employment.

For RQ2, we considered relevant to address the following survey questions:

- 1. To what extent do you think AI is influencing education and vocational training?*
- 2. Do you think employers are prepared to responsibly integrate AI to support the workforce?*

To continue, we decided to plot a comparison of responses based on gender to better understand how perceptions differ regarding AI's influence on education and employer preparedness for AI integration.

While the first graph illustrates how males and females perceive AI's role in education and vocational training, the second one allows us a direct comparison of their views on whether employers are ready to integrate AI technologies, or not in their activities. Such visualizations come in hand to highlight patterns and differences in opinions, providing a valuable insight into the overall perception towards AI adoption.

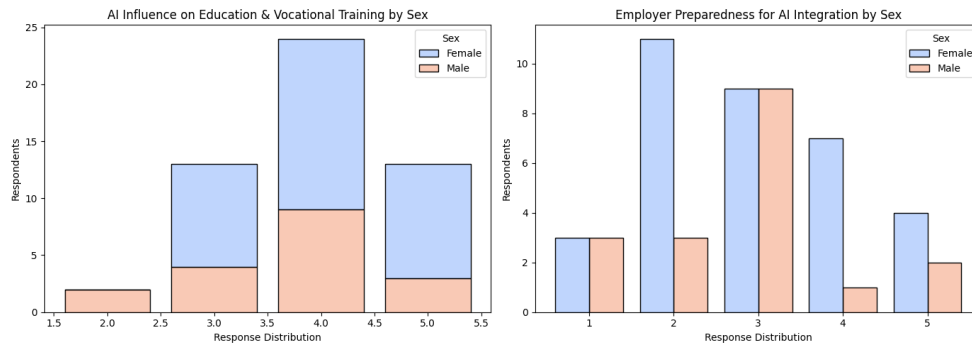


Figure 1. Perceptions of AI Integration in Education and Workforce by Gender
Made by authors. Sources: Deloitte Insights (2024), OECD (2023), World Economic Forum (2024), IBM (2024).

The clustered bar graph reveals that slightly more females perceive AI in education and vocational training as beneficial. However, the overall sentiment is positive across both groups, as responses tend to cluster around higher ratings. This suggests that AI is generally seen as an asset in these domains.

Moving along, the right-hand chart offers a side-by-side comparison of responses by gender regarding employer preparedness for AI integration. Interestingly, the most frequent response among females is equal to 2, indicating a notable level of skepticism about whether employers are ready to adopt emerging AI technologies. In contrast, male responses were more evenly distributed, suggesting a broader range of perspectives on the topic.

From this comparison, we can conclude that the perceived readiness of employers to integrate AI remains an open subject to be further explored. While some respondents acknowledge progress, especially, females express a level of doubt about whether organizations are sufficiently prepared. Additionally, males show a more diverse range of opinions, which could indicate varying levels of awareness or experience with AI implementation in the workplace. Given these differences, a deeper statistical analysis may be necessary to explore underlying factors influencing these perceptions.

Thus, with respect to AI deployment, corporate accountability should be in tandem with ethical AI adoption, where bringing fairness in employment ethos and workforce representation are imperative. Finally, AI integration in fields of education and employment needs to be guided by structured policies around human-centric job creation and continuous workforce development (Budhwar et al., 2023). This requires companies growing their own AI policies to be transparent, from explainable AI system best practices to ethical hiring guidelines, while investing in worker upskilling to boost productivity rather than just replace jobs through automation (Scott Dylan, 2024). Corporate ethical practices should also fall under the purview of regulatory frameworks that govern the responsible integration of AI, responsible decision-making, hiring and workplace practices.

This is especially important in generated educational activity, in which equal access to AI-powered learning tools is critical to prepare for work and socio-economic stability. Deloitte Insights (2024) suggest organizations to place emphasis on fairness audits and transparency measures into place to mitigate bias employment outcome, as AI strategies touch upon SDG 8 (decent work) and SDG 9 (industry innovation). We must bring about industry-wide ethical AI governance standards that ensures that AI is an enabler of workforce skills development, not just a driver of job displacement.

Regulatory frameworks also need to **hold corporations accountable for responsible incorporation of AI**, including ensuring that decision making, employment practices and workplace habits are mindful of AI and adhere to ethical guidelines.

Research Question:

I. How can global regulatory measures align to set ethical and employment-grade standards for AI-embedded educational engagements, thereby providing equitable access to AI-enabled learning resources and workforce preparation that minimize hindrances due to uneven access?

Related Survey Questions:

How important do you think it is for organizations to apply ethical standards in the use of AI?

Do you think the use of AI in education contributes to increasing employment opportunities?

Businesses are tasked against **AI-generated efficiency with fairness**. Companies must embed into their **organisational AI strategy, SDG 8 (decent work) and SDG 9 (industry innovation)**.) This calls for **regulatory oversight, corporate accountability, and a fair adoption of AI in employment and education** (Deloitte Insights, 2024). AI integration must stress **skills enhancement over displacement, connective economic growth** to sustain trust, **transparency measures** in the form of **explainable AI models and fairness audits** should be implemented by companies to avoid biases in employment outcomes (Scott Dylan, 2024).

Industry-wide **standardization of ethical AI governance frameworks** must be established with an emphasis on responsible AI practices aimed at **enabling sustainable workforce skillsets**.

5. Conclusions

Both transformational potential and ethical challenges are presented by the emergence of AI-enhanced educational activities, especially with regard to workforce transitions, fairness in AI applications, and global regulatory alignment. This study examined the crucial relationship between AI, employment, and

corporate responsibility, highlighting the necessity of formal ethical frameworks to prevent widespread job loss. Creating and implementing these frameworks is crucial to guaranteeing equity in job changes, especially in settings including professional training and education. AI-driven reskilling initiatives and fair job transition plans that assist displaced workers require cooperation between organizations and legislators.

Proactive steps must be taken to reduce biases in automated grading, admissions, and employment placements in order to promote inclusivity and fairness in AI-powered education. Transparency in AI decision-making, thorough bias audits, and the incorporation of diverse datasets that represent a range of socioeconomic and cultural backgrounds are all necessary to allay these worries. In order to prevent biased consequences and guarantee that AI functions as an augmentative rather than a deterministic instrument in influencing students' academic and professional prospects, equitable AI integration in education should place a higher priority on human monitoring.

Furthermore, developing uniform ethical and employability-grade standards for AI-driven educational interaction requires harmonizing global regulatory measures. Regulators can guarantee fair access to AI-enabled learning materials and lessen the inequities brought on by unequal access to technology by promoting international cooperation. By establishing international standards, organizations and businesses will be better able to maintain ethical responsibility and make sure AI's use in education helps prepare the workforce without widening socioeconomic gaps.

In the end, integrating AI in education and the workplace responsibly requires striking a balance between responsibility and creativity. To guarantee that AI is a tool for empowerment rather than exclusion in the developing digital economy, policymakers, educators, and corporate stakeholders must work together to create laws that protect employment opportunities, advance justice, and preserve ethical standards.

6. Suggested solutions for AI challenges

- **Principled AI Design:** Establishing ethical frameworks during designing AI and continuous assessment of AI behavior for compliance with the established standards.
- **Robust Education and Reskilling Pipeline:** Widespread, large-scale training programs for AI skills for the future workforce.
- **Cooperative Regulatory Actions:** Enactment of global policies governing AI that must coincide with updates to employment and educational policies.

Learn about transparent AI practices: Promoting open-source AI developments and explainable AI models to enhance trust and inclusivity in

educational activities.

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Ethical use of digital tools in medicine – a review on key-concepts and challenges

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Abstract: *In an era where technology is reshaping every aspect of our life, medical practice is subject to profound transformations as artificial intelligence (AI) is already modifying doctor-patient relationship, patient empowerment and doctor`s decision-making processes. Aiming at exploring the ethical dilemmas health professionals may experience as well as responsibilities and ethical challenges we tried to deepen our understanding of how the digital realm may impact our awareness and ability to facilitate a high-quality medical act having as always patient`s well-being in the forefront of our values. We explored topics such as data confidentiality, protection, digital literacy, ethical use of digital tools with a focus on telemedicine, mobile devices and generative AI trying to offer a critical and comprehensive ethical perspective on the questions the digital environment poses onto us, as professionals as well as patients. Focusing on keeping the essential out of the medical services digitalization we encouraged a balanced approach as well as highlighting the urgent needs of guidelines and policies for including digital tool as assistants in our current medical practice.*

Keywords: digital ethics, medical practice, digitalization, ethical, artificial intelligence.

1. Introduction

Digitalization and artificial intelligence (AI) technologies face challenges from socio-technical dogmatism and technological skepticism, which highlight academics' concerns over the ethical issues related to rights, virtues, and consequences (Watson et al., 2024). Socio-technical dogmatism is a notion that emphasizes the capacity of technological advancement to drive economic and social development (Andreessen, 2023), guaranteeing a prosperous future as long as it is not impeded or constrained (Kurzweil, 2005). Conversely, socio-technical skepticism emphasizes technology's potential to inflict damage or intensify existing social and economic injustices and inequities. The latter pertains to the necessity for increased laws, encompassing enhanced supervision of the design and utilization of AI systems. Socio-technical pragmatism is a paradigm that constructively integrates both views, emphasizing the historical contradictions

between the necessity of utilizing technology and the obligation to comply with existing regulations governing its usage (van Dijk, 2024). Prominent contemporary philosophers contend that the effects of digitalization and AI predominantly hinge on design (Floridi, 2021) and argue that ethical discussions surrounding AI-driven decision-making must consider social inequality (Kearns & Roth, 2019), while other scholars stress the necessity of regulation prior to innovation (Mesko et al., 2023). In medicine, we must emphasize patient safety and benefits, which entails utilizing current technology to produce new pharmaceuticals or to diagnose properly. Indeed, there exists bureaucracy associated with training the reactions of these digital instruments, as well as limitations on the future advancement of life-saving AI-based treatments. Consequently, a genuine ethical conflict emerges between innovation, regulation, and growth, as well as between pro-social and pro-corporate results (Watson et al., 2024).

During the COVID-19 pandemic, efficiency and time savings were demonstrated; nevertheless, difficulties related to data utilization in healthcare and research necessitate an ethical revision that incorporates humanistic and civic values (Seroussi et al., 2024). In an age where digital technology is sufficiently advanced to induce significant usage mistakes, and its prevalence is expected to persist in the next decades, the paradigm of patient care will undergo transformation. However, in what manner? Unethical behaviors can engender suspicion, anger, and frequently unwarranted disputes in the doctor-patient relationship (Hansson et al., 2024). Technologies like as telemedicine, artificial intelligence algorithms, medical data, self-monitoring, and electronic medical records can enhance the quality of patient treatment. From an ethical standpoint, the notions of digital accountability and "digital empowerment" for patients may evolve, necessitating informed strategies from medical practitioners, while the paternalistic dynamic with a new authoritative entity represented by the digital system will inevitably transform patient interactions with healthcare professionals (Mesko et al., 2017; Seroussi et al., 2024). Digital ethics in medicine upholds fundamental medical ethical principles, including autonomy, confidentiality, beneficence, justice, and non-maleficence, while applying the ethical standards of in-person healthcare to digital service delivery (Beauchamp et al., 2019).

2. Methods

We employed a mini-review methodology integrating existing literature from multiple academic sources, focusing on recent advancements and databases such as PubMed, Scopus, and Google Scholar. The search strategy included key terms such as "digital ethics in medicine," "artificial intelligence in healthcare," "telemedicine ethics," "electronic medical records security," "data privacy in digital health," and "ethical decision-making in AI-driven healthcare." We prioritized peer-reviewed journal articles, books, and policy reports published in the last years, with a particular focus on publications from 2022 onward. Key ethical dilemmas, including decision-making transparency, algorithmic bias, patient empowerment,

and data security, were identified and critically examined. A thematic analysis was conducted to extract the most relevant ethical concerns and recommendations for medical practitioners and policymakers.

3. Digital ethics principles in medicine

The digital aspect of medical ethics incorporates the social, technological, cultural, and political frameworks within which services are delivered, with digital implementation presenting challenges concerning privacy, security, data protection, transparency, equity, accessibility, and digital accountability (Seroussi et al., 2024). Among the medical ethical principles pertinent to digital ethics, we highlight the principle of autonomy: honoring patients' rights to make informed decisions regarding their care, now revised to encompass consent for data utilization in health interventions within telemedicine or health monitoring applications, which introduces dilemmas concerning decision-making accountability (Hansson et al., 2024); beneficence: the imperative to guarantee that the employed technologies serve exclusively the patient's benefit and do not adversely impact the outcomes of digital interventions, including the necessity to ensure that the initial design of these technologies adheres to ethical standards; Non-maleficence entails the prevention of harm to patients resulting from the improper, negligent, or malicious application of digital technologies, errors in evaluation, diagnosis, and treatment by algorithms, reliance on medical critical thinking, and the emergence of cognitive biases due to excessive dependence on digital technologies, alongside the implications for professionals' digital competencies (Choi et al., 2024). Justice involves ensuring equitable access to health-promoting technologies, preventing the digital literacy deficit from adversely affecting patient health, and addressing issues of digital inequity or exacerbating existing inequalities (Lang et al., 2023; Nickel et al., 2024). The principle of confidentiality now encompasses safeguarding against unauthorized data access on digital platforms and preparing for medical emergencies where confidentiality may be compromised (Floridi et al., 2021; Lang et al., 2023; Hansson et al., 2024).

4. Ethical usage of digital tools

Whether we are discussing electronic medical records, telemedicine platforms, AI-based diagnostic tools, or mobile health applications, these tools have already proven their efficiency, accuracy, and ease of accessibility. Thus, specific ethical challenges deserve to be debated considering the risk of increasing inequity in healthcare provision (Cheshire et al., 2022; Lewis et al., 2024).

4.1 Electronic medical records

Electronic medical records enhance the efficiency of patient treatment by promoting cooperation and accessibility, while simultaneously improving patient

compliance and quality, and decreasing medical mistakes (Ozair et al., 2015). Ethical considerations encompass confidentiality and data protection, which may be compromised by sensitive material that can readily result in isolation and stigmatization. Consequently, securing consent must be a paramount consideration for professionals when permitting third-party access to documents. The capacity to input data, ensure its accuracy, and enable exchange with other information systems without compromising the data's meaning can be undermined by errors, resulting in consequences such as insufficient diagnoses, modified treatments, and diminished patient prognosis, among others (Paccoud et al., 2024).

4.2 Artificial intelligence technology

Artificial intelligence (AI) denotes a computer or software's capacity to emulate intelligent human behavior, execute rapid computations, resolve issues, and assess fresh data based on prior evaluations (Tang et al., 2023). This technology represents a singular opportunity for the advancement of healthcare by transforming professional duties and enhancing workflow and administrative efficiency, all while promising patient-centered treatment (Hansson et al., 2024). The transparency of AI-based algorithms, defined as a comprehensive knowledge of the mechanisms by which AI generates solutions, would greatly enhance the confidence of both professionals and patients (Kenig et al., 2024). Furthermore, experts must elucidate to patients the concepts underlying this technology, which is immediately engaged in the medical procedure, but only when they possess a comprehensive understanding of it (McCoy et al., 2024). A crucial subject is the necessity of ongoing human supervision and the entire assumption of accountability in medical choices, viewing AI technology as a supportive tool rather than a total substitute for professionals (Talyshinskii et al., 2024). Research indicating patients' perspectives towards AI now reveals an optimistic perspective; but, concurrently, they see threats to their safety, privacy, and autonomy (Bahadir et al., 2024). Discussions suggest that the autonomy to determine the inclusion or exclusion of AI in medical practice, to challenge the diagnosis, and to receive an explanation of the diagnosis, is exclusively the patients' prerogative. Significant worries exist over the privacy and security breaches of medical data for both patients and professionals; nonetheless, this is unavoidable since machine learning algorithms necessitate extensive data for development (Rogers et al., 2021). Currently and in the near future, patients will not obtain a direct diagnosis from a machine learning software; instead, it will serve as one of the resources utilized by the diagnosing physician (Ploug & Holm, 2020).

4.3 Decision-making

Decision-making is a critical component in the discourse on digital ethics in medicine, as AI-driven judgments appear to lack transparency (Yu et al., 2022). Artificial intelligence might exacerbate pre-existing prejudices within the medical sector due to the inherent bias in the testing dataset, which can result in erroneous

and biased learning, hence perpetuating inequities and producing misleading predictions (Ionescu et al., 2024; Obermeyer et al., 2019). A further problem may arise from digital paternalism in the therapeutic interaction characterized by the "algorithm/computer knows better" paradigm (Risling et al., 2017). Conversely, a departure from the conventional paternalism of physicians, manifested as the "medical emancipation" of patients, may result in an increased moral accountability for the firms developing the AI systems. A significant issue with algorithms is that their failures can result in errors that people do not often commit (Alvarado, 2022). AI cannot rectify these errors independently and may persist in generating anomalous outcomes, in contrast to humans who can amend their own faults. Finally, once an AI system gains access to extensive data capable of predicting health and sickness, can we contemplate the potential for AI algorithms to categorize patients as "winners" and "losers" in the context of disease?

4.4 Telemedicine

Increased availability of virtual consultations can yield advantages, including enhanced convenience for patients and improved access and comfort for experts. The standard of medical treatment in the digital age should match that of conventional medical care, and practitioners must distinctly determine whether traditional consultation is warranted for the patient. The omission of a physical examination, a specific nuance disregarded, may lead to compromises for convenience, as severe conditions like atrial fibrillation or valvular diseases can pose critical challenges in making complex decisions where the physical examination is vital for identifying subtle signs. Telemedicine now yields varying degrees of patient satisfaction, and rigor is a crucial element for enhancement (Adams et al., 2021). Nonetheless, if in-person consultations are intrinsically superior, the proliferation of telemedicine might inadvertently create a dual system for already marginalized patients, so intensifying structural disparities (Tolchin et al., 2020; Hull et al., 2022).

4.5 Mobile health applications

Concerning mobile health applications, medical professionals should ensure that both they and patients fully understand which third parties may have access to the data collected (Deniz-Garcia et al., 2023). Additionally, the recommendation of these applications should be made only after rigorous documentation and not involving other individual or institutional conflicts of interest. Having clear benefits in self-determination and empowerment in rapid accessibility or reducing stigma, this self-management approach may not benefit certain vulnerable groups such as those suffering from mental disorders. Professionals need to ensure that self-monitoring is truly appropriate to the individual resources of patients, resources that include aspects of digital literacy, among others (Morley et al., 2020). Taking the subject of autonomy further, it is worth mentioning that it can

easily become an ambivalent concept, leading self-monitoring to acquire a disciplinary effect, forcing patients into a routine dictated by technical equipment (Rubeis et al., 2022). This contradicts personalization, one of the supposed main advantages of mobile applications, so that when users must adapt to technology instead of technology being tailored to their needs and resources, self-determination is challenged (Morely & Floridi, 2020). This can be perceived as a severe burden and a psychological stress factor by users (Mittelstadt & Floridi, 2016). At the same time, Big Data technologies are inherently data-hungry and require increasingly larger datasets to provide useful results and be validated. The total volume of collected data poses the risk that users may not be able to monitor what data is being used and for what purpose (van Genugten et al., 2020; Rubeis, 2022).

4.6 Datafication

Over the last decades, the capacity to collect, store, and analyze individuals' physiological, behavioral, and locational data has influenced several aspects of daily life, including entertainment, education, urban planning, and epidemiology (Anderson, 2008). Datafication in medicine transpires at several levels, encompassing data-driven medical research and public health infrastructures like biobanks and public databases, along with fitness and health equipment and smartphone applications. Data extraction frequently necessitates reduction and oversimplification, perhaps overlooking the distinctiveness of the patient's experiences. Furthermore, the data requires pre-processing, necessitating the definition of variables for the systems to generate them (Abbe et al., 2016). In this regard, the potential for prejudice obviously emerges. Furthermore, patient information may be "translated" into a predefined schema, so reducing individual features to conventional domains (Becker et al., 2018), a process already driven by the cost efficiency of therapies and data collecting (de Laat, 2019). Consequently, the emphasis transitions from the individual to the collective. Consequently, customization, the primary aim of contemporary medicine, may face ethical scrutiny (Tai et al., 2019). It is essential to highlight biases, particularly when analyzing the data of a person whose traits are absent from the machine learning training dataset (Challen et al., 2019). Consequently, we are examining ethnic, gender, and particularly socioeconomic variables that may significantly influence this process when they lack transparency (Carr et al., 2020).

5. Discussions and perspectives

Advancing digital ethics principles in medicine needs the reassurance that innovation will serve as enhancing human expertise not replacing it. Regular updates with the technological advancements and ethical principles alignment should include openness, patient autonomy and of course, digital equity. We advocate for regulatory guidance and supervision as the consequences of healthcare

access inequities will undermine health systems and society. Telemedicine, mobile health applications will enhance accessibility but there is need to consider the importance of the quality of patient-physician interaction as one of the most important clinical challenges digital medicine will put. Our reflection made us question whether digital inequity will lead to overprescription of telemedicine interactions rather than physical ones in the name of accessibility. More than that, we are concerned that human supervision in decision-making practices should be a key-concept and priority to mitigate the risks of automation biases. We support the concept of collaborative strategy including lawmakers, medical professionals and digital specialists to facilitate the development of regulatory frameworks suitable for Romania in relationship with the current technological advancements having as the main aim patient well-being and the integrity of medical professionals.

From an educational perspective we actively contributed by creating in 2023 the first course of Digital Ethics in Medicine in Romania for first-year medical students thus helping to lay the basics of digital ethics theoretical foundations and awareness among future doctors.

6. Conclusions

The integration of digital instruments in medicine offers tangible advantages to medical practice, although it also presents several ethical dilemmas that we have endeavored to delineate above. It has frequently been underscored that AI systems need to serve as instruments for experts rather than substitutes. This concept can only be implemented effectively if top decision-makers acknowledge the risks associated with the depersonalization of healthcare. From a social justice point, there is a significant danger that those with little resources would resort to inexpensive health applications instead of seeking consultation with a healthcare expert.

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Bibliometric analysis of ChatGPT based on Scopus data: Global research trends (2022–2024)

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Abstract: *The emergence of ChatGPT has reshaped academia and research, generating both enthusiasm and concerns. While ethical challenges persist, a growing movement advocates for its integration and the adoption of best practices. **Objective:** This study conducts a bibliometric analysis of scientific publications on ChatGPT indexed in Scopus (2022–2024) to map trends and characterize the academic output related to this technology. **Methods:** A systematic bibliometric analysis was performed following the PRISMA protocol. Data were extracted from Scopus, identifying 437 relevant publications. A statistical analysis using VOSviewer enabled the identification of 13 clusters and 32 nodes. **Results:** The analysis revealed that the majority of publications originated from the United States (24.80%), India (11.17%), and China (11.17%). The predominant publication types were journal articles (45.3%) and conference papers (36.8%). The most active research fields include Computer Science (27.7%), Medicine (14.5%), and Social Sciences (13.2%). **Conclusions:** Findings underscore the increasing prominence of ChatGPT as an interdisciplinary research topic. Key areas of focus include: the evolution of language models, response accuracy, impact on education and healthcare, and challenges and opportunities that AI presents in academic research.*

Keywords: ChatGPT, Bibliometric Analysis, Scientific Production, Scopus.

1. Introduction

In recent years, advances in artificial intelligence (AI) have shaped the way multiple tasks are performed (Makridakis, 2017; Burgos et al., 2023). In this context, significant changes are also occurring within the scientific community regarding traditional research methods (Aguilar et al., 2023; Dwivedi et al., 2023).

The emergence of ChatGPT has not only provided a supportive tool for tasks related to research work but has also become a subject of study. On the one hand, the ethical implications of its use are being analyzed (González Arencibia & Martínez Cordero, 2020), and on the other, the advantages and challenges of its incorporation into research activities are being evaluated (Yu, 2023).

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Despite the debate surrounding the use of ChatGPT in scientific writing (González Arencibia & Martínez Cardero, 2020; Salvagno et al., 2023), there is a growing movement advocating for its implementation across various fields (Agudo-Peregrina, 2019; Lopezosa, 2023; Goyanes & Lopezosa, 2024). This movement comprises researchers, academics, and professionals who recognize the potential of ChatGPT to transform research and education (Deng & Lin, 2022; Burgos et al., 2023; Mejía Rivera & Rivera García, 2023).

In terms of its application, ChatGPT is being utilized in various ways within the scientific community (Castillo-González et al., 2022; Chen, 2023; Dergaa et al., 2023). Researchers use this model to generate drafts of academic papers, analyze large sets of qualitative data, and assist in creating summaries and literature reviews (Chen, 2023; Rahman et al., 2023). Additionally, its use as a pedagogical tool is being explored, helping students understand complex concepts and improving their writing skills (Mejía Rivera & Rivera García, 2023).

ChatGPT is also employed in the peer-review process (Mehta et al., 2024), where it can help identify errors and suggest improvements to manuscripts. Collectively, these applications demonstrate how ChatGPT is being integrated into research activities, providing new capabilities, and boosting scientific productivity (Castillo-González et al., 2022). Building on these ideas, it is crucial to understand how ChatGPT is being utilized in scientific production (Reyes Flores & Mejía Rivera, 2024), particularly in indexed publications. This understanding is essential for the scientific community to progress more rapidly and effectively, maximizing the capabilities of ChatGPT while simultaneously addressing the challenges its use may pose, including required regulations. The research question that guided this study was: What are the publication trends and disciplinary distributions of ChatGPT research in Scopus from 2022 to 2024?

2. Methodology

The applied methodology was the PRISMA protocol (Moher et al., 2009) which ensures a series of guidelines for reporting systematic reviews (Espinal et al., 2024; Torres et al., 2024). As shown in Figure 1, a search was conducted for titles, abstracts, and keywords of publications available in the Scopus database through the ChatGPT search command [TITLE-ABS-KEY(ChatGPT)]. The results were then cleaned to verify their relevance and remove duplicates. Finally, a statistical analysis was performed using VOS Viewer software to visualize relationships, identify associations, and clustering the analyzed publications.

The selection of Scopus as the sole source for this analysis is justified by its extensive coverage and high-quality data, ensuring the inclusion of top-tier publications. Scopus provides consistent and normalized data, facilitating comparisons and its advanced tools enable detailed analyses and visualization of trends, collaborations, and impact.

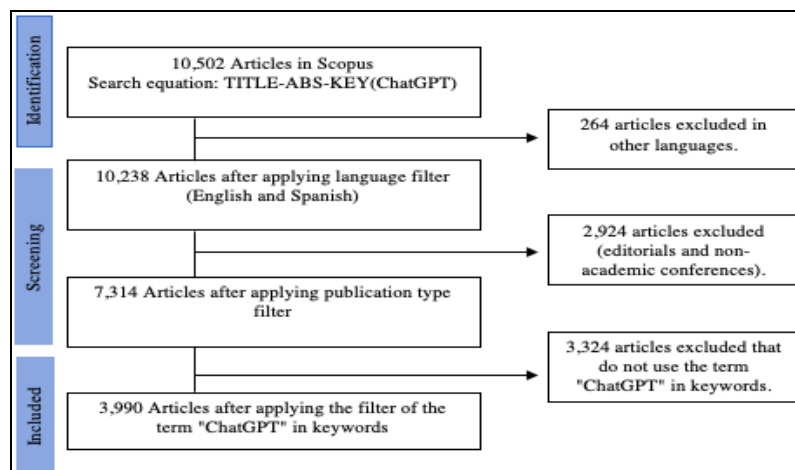


Figure 1. PRISMA flow diagram for the systematic literature review

2.1 Inclusion and exclusion criteria

Table 1 presents the inclusion and exclusion criteria defined for the selection process of the articles included in this bibliometric analysis.

Table 1. Selection criteria for publications

Element	Inclusion Criteria	Exclusion Criteria
Language	English and Spanish	Languages other than English and Spanish
Article Type	Academic journals or conferences	Conference abstracts
		Duplicate articles
Topic	ChatGPT	Unrelated to ChatGPT

Based on the criteria outlined, an initial search was conducted in the Scopus database in September 2024, yielding 10,502 articles. This initial search required the application of filters that considered the exclusion criteria. Consequently, the search excluded publications written in languages other than Spanish and English, publications in press at the time of the search, as well as publications such as letters to the editor, conference reviews, notes, and short surveys. This process resulted in the selection of documents that met the inclusion criteria and served as the basis for the bibliometric analysis conducted in this study.

3. Findings

The results indicate that Scopus contains 3,900 publications related to ChatGPT. The majority of these publications are affiliated with institutions located in the United States (24.80%), India (11.17%) and China (11.17%), as shown in Figure 2.

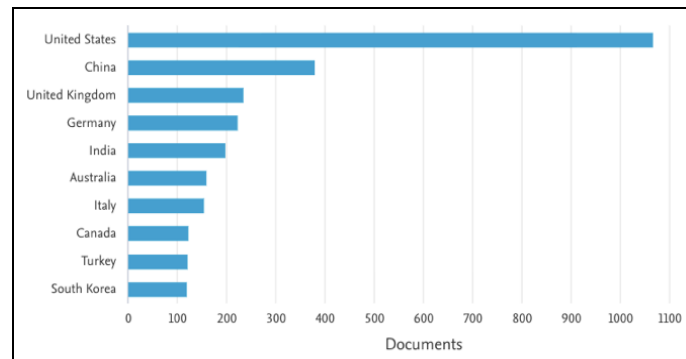


Figure 2. Publications by country. Source: Scopus

Among the indexed publications, 45.3% consist of journal articles, while 36.8% correspond to conference papers, as show in Fig 3. The academic fields with the highest number of publications are Computer Science (27.7%), Medicine (14.5%), and Social Sciences (13.2%).

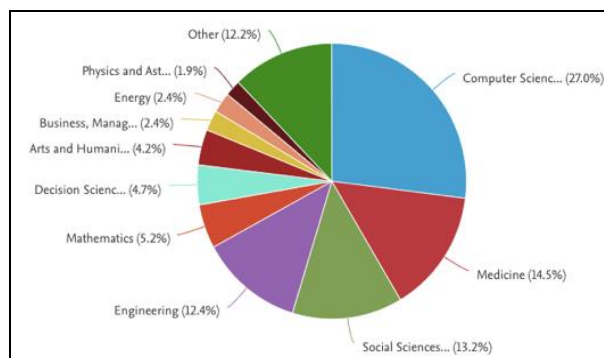


Figure 3. Publications by country. Source: Scopus

The mapping also identified leading affiliations (Fig. 4) and the most prominent authors based on number of publications. These include Ishith Seth and Warren Matthew Rozen, Wisit Cheungpasitporn, Charat Thongprayoon, Jing Miao, Jérôme Rene Lechien, Luigi Vaira, Zohar Elyoseph, and Carlos Chiesa-Estomba.

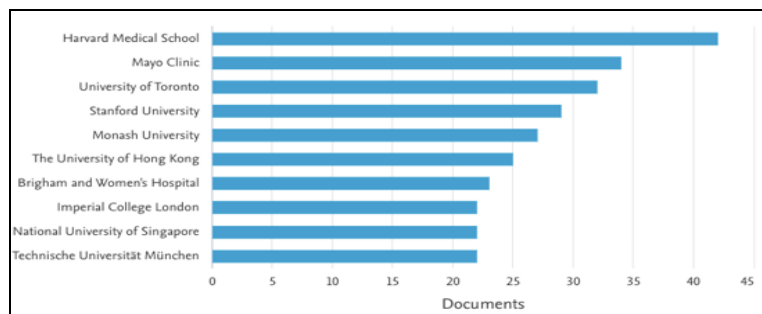


Figure 4. Leading institutional affiliations. Source: Scopus

The analysis of sponsoring institutions which have funded the largest number of ChatGPT-related publications over the past two years, reveals a notable presence of organizations from the United States and Asia.

Figure 5 illustrates the network of relationships by clusters revealed through the bibliometric analysis using VOSviewer. This network highlights a significant concentration of co-occurrences centered around the "ChatGPT" node, which is linked to 13 clusters comprising a total of 32 nodes. Key nodes such as performance, question, challenge, and higher education indicate major areas of study within the academic community. Peripheral nodes, such as case study, comparative study, perception, and generative AI, also demonstrate relevance, suggesting that research on ChatGPT encompasses both experimental studies and user perceptions, particularly in educational contexts.

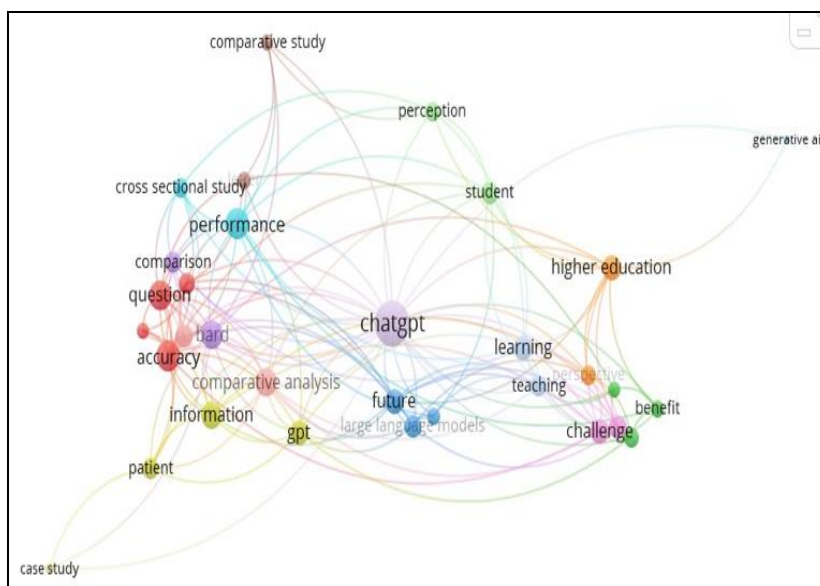


Figure 5. Clusters relationships identified. Source: VOS Viewer

The breakdown of data by clusters indicates that "ChatGPT" node has the highest number of co-occurrences (1,039) and link strength (646), underscoring its centrality in the research. Other key terms, such as performance (76), accuracy (32), and higher education (29), highlight the diversity of topics being investigated, as shown in Figure 6. Overall, this analysis reveals a growing interest in ChatGPT across various academic disciplines, with a tendency to explore its accuracy, applications, benefits, and challenges.

The cluster 1 includes concepts such as "future", and "large-scale language model". This reflects the academic community's focus on the future implications and utilization of large-scale language models. This highlights a strong interest in communication and language, particularly in how advanced language models can

evolve and revolutionize various fields of knowledge. The inclusion of "future" suggests optimism within the research community regarding the transformative potential of these technologies, anticipating significant advancements that could reshape the way people interact.

The second cluster, with terms such as "question", highlights the importance of accuracy and utility of ChatGPT's responses, determining the effectiveness of these technologies in daily life. This cluster reflects the need for language models to understand and appropriately respond to human queries, which is essential for their acceptance and success in practical applications. Respectively, the third cluster addresses the "benefits" and "risks" of AI technologies. The potential benefits are substantial, including increased efficiency, access to information, and new opportunities across various industries. However, it is also vital to consider risks such as privacy, security, and ethical implications.

Cluster	keywords	Link	link strength	Co-occurrences
	Comment	6	21	17
1	Future	11	38	27
	Large language models	9	21	15
	ChatGPT responses	5	8	12
2	Correspondence	8	27	13
	Question	14	81	43
	Benefit	6	20	12
3	Risk	5	22	13
	Information	12	49	28
4	Patient	8	36	22
	Learning	11	36	27
5	Teaching	8	29	21
	Challenge	11	65	39
6	Opportunity	10	63	38
	Higher education	11	44	29
7	Perspective	7	29	22
	Comparative analysis	13	35	16
8	Quality	10	24	13
	Perception	7	39	28
9	Student	9	62	43
10	Accuracy	15	55	32
11	Bard	13	53	24
12	Case study	3	20	20
13	Chat GPT	30	646	1,039
14	Comparative study	5	25	19
15	Comparison	8	34	18
16	Letter	6	35	18
17	Cross sectional study	7	22	12
18	Generative IA	2	13	12
19	Gpt	11	36	20
20	Limitation	7	23	15
21	Performance	16	123	76

Figure 6. Clusters relations identified. Source: VOS Viewer

The fourth cluster, with terms such as "information" and "patient," focuses on the healthcare sector. This cluster reflects the critical intersection between technology and medicine, where AI innovations can lead to significant improvements in health outcomes and the efficiency of medical care. In contrast, the fifth cluster emphasizes the impact of language models on education, with terms such as "learning" and "teaching". AI technologies have the potential to transform education by offering new pedagogical methodologies and personalizing

learning to better meet individual students' needs.

Encompassing terms like “challenge” and “opportunity”, the sixth cluster reflects the balance between the challenges and opportunities presented by new AI technologies. While significant obstacles exist, such as overcoming technical and ethical barriers, there are also numerous opportunities for innovation and advancement across various fields. Simultaneously, the seventh cluster focuses on higher education and future perspectives, with words such as "higher education" and "perspective." This emphasizes the importance of academic perspectives in integrating and applying emerging technologies in higher education settings.

The eighth cluster, which includes "comparative analysis" and "quality," underscores the importance of benchmarking and quality in research on language models. Rigorous evaluation and systematic comparison are essential for understanding the strengths and limitations of these technologies, ensuring their effective and responsible implementation. Meanwhile, the ninth cluster reveals an interest in students' perceptions and experiences with AI technologies in education, with terms such as "perception" and "student". This indicates that student perception is crucial to the adoption and effectiveness of new educational tools. The acceptance and success of these technologies depend largely on how they are perceived and used by students.

Regarding the tenth cluster focuses on the accuracy and performance of language models, with terms such as "accuracy" and "performance." The high frequency of these terms underscores the importance of ensuring these technologies are effective and reliable. Accuracy and performance are critical factors that determine the practical utility of language models in various applications, from natural language processing to automated decision-making. In parallel, in the eleventh cluster, the mention of "bard" suggests a specific reference to a study or application, while "case study" indicates a focus on detailed analyses of specific cases. This cluster reflects an interest in better understanding the impact of these technologies through specific and detailed studies, providing valuable insights that can inform future research and developments.

The twelfth cluster shows a strong concentration on ChatGPT, with a very high frequency of "ChatGPT," outlining its central relevance in current research. This suggests considerable interest in exploring the capabilities and limitations of ChatGPT, as well as comparing it with similar technologies. Finally, the thirteenth cluster, with terms such as "limitation" identifies limitations and performance, suggesting a critical focus on identifying areas for improvement in language models.

4. Discussion

The bibliometric analysis developed confirm that ChatGPT research is expanding in academic literature, adopting a multidisciplinary approach that spans education (Goyanes & Lopezosa, 2024), medicine (Burgos et al., 2023), and computational

linguistics (Biswas, 2023). Findings underscore ChatGPT's prominence as an interdisciplinary research topic with diverse applications (Kalla et al., 2023; Singh & Singh, 2023). The key nodes identified through VOSviewer reveal major research axes in the analyzed publications: performance, question, challenge, and higher education.

The node "performance" highlights the importance of accuracy and efficiency in generative AI models, as emphasized by researchers (Kasneji et al., 2023). These factors are crucial for AI applicability across disciplines, ranging from computational linguistics (Liu et al., 2023) to automated decision-making in healthcare (Coskun et al., 2023; Lim et al., 2023). This suggests that the scientific community increasingly acknowledges the long-term implications of ChatGPT's usage and its reliance on large-scale language models trained on extensive textual data (Hassani & Silva, 2023).

The "question" node reflects concerns about the precision and utility of ChatGPT-generated responses (Kuşcu et al., 2023). This highlights two key issues: first, the need to enhance models' ability to comprehend and adequately respond to human queries (Deng & Lin, 2022; Elkhatat, 2023); and second, the necessity of proper training to create effective prompts (White et al., 2023) and ensure digital literacy, which is essential for maximizing ChatGPT's potential while upholding ethical usage practices (Dave et al., 2023).

The "challenge" node captures the dichotomy between the opportunities and challenges posed by AI technologies (Gill & Kaur, 2023). While innovation, increased efficiency, and cost reduction are among its primary benefits (Deng & Lin, 2022), major concerns persist, including security and privacy risks, reliability and accuracy issues, quality control, environmental impact, and cultural implications (Ray, 2023).

Finally, the "higher education" node emphasizes that ChatGPT's emergence has sparked a significant debate within academia, yet no clear consensus has been reached. Nevertheless, its growing integration into teaching and learning processes is undeniable. This necessitates the involvement of governments, industry, and higher education institutions in regulating and overseeing its use, establishing protocols, and fostering the training of future professionals. Ensuring ethical and effective utilization of AI tools in academia remains a critical priority.

The co-occurrence bibliometric analysis suggests that discussions on ChatGPT's impact are still in their early stages. The distribution of document types reveals that the majority are articles (2,582), followed by conference papers (1,318), suggesting a solid combination of established research and emerging discussions in academic spaces such as international conferences. Additionally, content analysis demonstrates a wide variety of terms and thematic approaches, with 8,633 keywords provided by authors. These data underscore the depth and breadth of research on ChatGPT, characterized by high collaboration, both in the number of co-authors per document (3.98) and in the diversity of keywords used,

which could be linked—based on cluster analysis—to its implications across different spheres of scientific research.

5. Conclusions

Research trends on ChatGPT literature include its evolution in language models, performance and response accuracy, benefits and risks, impact on health and education, challenges and opportunities of AI and perspectives on higher education.

The bibliometric analysis reveals a significant concentration of co-occurrences around the "ChatGPT" node, connected through 13 clusters comprising 32 nodes. Key nodes such as performance, question, challenge, and higher education indicate major areas of interest and study within the academic community. Peripheral nodes, such as case study, comparative study, perception, and generative AI, also demonstrate relevance, suggesting that research on ChatGPT encompasses both experimental studies and user perceptions, particularly in educational settings.

The analysis reveals a growing interest in ChatGPT across various academic disciplines, with a tendency to explore its applications, benefits, and challenges in higher education, task performance, and precision. Results show that international collaboration is significant, with 23.59% of co-authorships involving researchers from different countries, indicating a global and multidisciplinary approach to ChatGPT research, even within such a short time frame.

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Students' perspectives on the adoption and use of AI tutoring systems in higher education using UTAUT2

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Abstract: *The integration of AI in education has led to the emergence of AI tutoring systems. These systems aim to create personalized learning experiences through the utilization of machine feedback. Despite their increasing prevalence, doubts remain regarding the efficacy, adaptability, and student receptiveness of AI tutoring systems. This necessitates further investigation into AI tutoring systems from the learner's perspective. Moreover, there is insufficient study regarding students' perceptions and responses to AI tutoring systems. This study aimed to quantitatively examine students' perceptions and experiences about AI tutoring systems utilizing UTAUT2. After collecting survey responses from 220 undergraduates, we analyzed the data using SPSS statistical software. The results indicated the presence of favorable correlations among the elements included in the framework. The PE, FC, HT, and HM exert a considerable influence on the BI, as indicated by multiple linear regression analysis. Behavioral Intention (BI) has a big effect on AI tutoring systems' Use Behavior (UB), but Effort Expectancy (EE), Social Influence (SI), and Price Value (PV) have almost no effect on BI. Academic professionals and learners might anticipate the study's findings to be useful for future research.*

Keywords: AI Tutoring Systems, UTAUT2, Students' Perspectives.

1. Introduction

The rapid development of artificial intelligence (AI) has significantly contributed to the massive shift occurring in the Higher Education (HE) sector. Research in that field has led to the development of several learning systems that use AI. These systems include learning analytics and tutor systems (TS). Computer-based educational solutions that use advanced artificial intelligence (AI) to provide students with personalized instruction and support are known as AI tutoring systems (AITS). Obviously, there is enormous promise that AITS will revolutionize the education process. We can tailor the instructional approach to each student's needs. Tailoring lessons to the needs and learning styles of each learner (Rızvı, 2023) helps improve educational outcomes.

Student seeks to assist tutors in various ways. In essence, AITS tailor education to accommodate students' requirements, interests, and learning tempo.

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By providing students with personalized feedback and recommendations, such technologies have facilitated more efficient learning in HE. Students in HE relies on AITS for academic support. It emerged as the educational alternative with the highest potential and appeal (Mounkoro et al., 2024).

AITS such as ChatGPT, Khan Academy, Quizlet, and Duolingo possess the ability to markedly enhance the quality and efficiency of educational activities, including the creation of tailored content, assistance with assignments, and provision of feedback to students. Numerous pupils currently benefit from these initiatives. Approximately two-thirds of AITS users successfully finish all their homework, assignments, and essays (Nipun et al., 2023). Due to their significant utility in the educational process, higher education students have become fully reliant on, or even addicted to, AI tutoring systems. In the long term, these tools may either benefit or detriment students. Therefore, researchers should continuously assess AI tutoring systems (AITS) to ensure their outputs align with student expectations. Furthermore, previous studies necessitate additional investigation into the adoption of AITS (Habibi et al., 2023; Keshtkar et al., 2024).

The current study examines the AITS within the UTAUT2 framework. UTAUT2 has been widely employed in the educational sector to examine the adoption of new technologies by both students (Cabero-Almenara et al., 2024) and educators (Ateş & Gündüzalp, 2025). The implementation and adoption of AITS systems in higher education rely on several factors, including students' behavioral intention (BI) and use behavior of AITS during learning. The Unified Theory of Acceptance and Use of Technology (UTAUT2) could serve as an assessment tool. UTAUT2 is ideally suited for higher education, capable of identifying barriers to adoption and predicting future utilization. UTAUT2 exceeds earlier models by incorporating an increased number of characteristics that affect users' propensity to embrace and maintain technology usage. The model incorporates factors such as performance expectancy, effort expectancy, social influence, and facilitating conditions. The factors include hedonic motivation, habit, price value, behavior intention, and use behavior (Slepankova, 2021). The study investigates students' intentions to utilize AITS by analyzing the primary components of UTAUT2, which encompass performance expectancy (PE), effort expectancy (EE), social influence (SI), facilitating conditions (FC), hedonic motivation (HM), habit (HT), price value (PV), behavior intention (BI), and use behavior (UB) of AITS. Educators and developers aiming to implement efficient AI-tutoring systems would significantly benefit from the findings.

2. Material and methods

The research sought to comprehend students' perspectives of AITS through a quantitative methodology. An online questionnaire was conducted to collect data. The study included a sample of 220 out of 242 undergraduates, encompassing a diverse age range. Researchers selected participants for the study from nine distinct

Iraqi universities based on their approachability and accessibility. The form was segmented into three sections. Section One's demographic data includes inquiries regarding age, gender, and university. Table 1 presents a comprehensive analysis of the student's demographics.

Table 1. Demographic information of students

Students' Characteristics		Frequency	Percent
Gender	Male	136	61.8
	Female	84	38.2
Age	18–20	55	25.0
	21–23	121	55.0
	24–26	34	15.5
	27 and above	10	4.5
University	Tishk International University	127	57.7
	Soran University	8	3.6
	Salahaddin University	12	5.5
	University of Sulaimani	11	5.0
	University of Raparin	22	10.0
	Cihan University	19	8.6
	Lebanese French University	12	5.5
	Garmian university	3	1.4
	Koya university	6	2.7
	Total	220	100.0

The second section inquires about the utilization of AITS, including the frequency of student usage, their objectives for using, and any encountered difficulties. Table 2 displays the frequency and percentage of inquiries from Section 2.

Table 2. AI Tutoring Systems Usage

AI Tutoring Systems Usage		Frequency	Percent
The most AITS students use	ChatGPT	208	94.5
	Khan Academy	7	3.2
	Duolingo	26	11.8
	Socratic by Google	8	3.6
	Quizlet	9	4.1
Frequency of using AITS	Daily	113	51.4
	Several times a week	72	32.7
	Once a week	21	9.5
	Rarely	14	6.4
Purpose of using AITS	Solving academic assignments	121	27.5%
	Exam preparation	97	22.0%
	Learning new concepts	120	27.3%
	Research assistance	102	23.2%
challenges while using AITS	Lack of accuracy in responses	67	23.2%
	Difficulty in understanding complex topics	84	29.1%
	Limited availability (e.g., server issues)	93	32.2%
	Ethical concerns (e.g., plagiarism)	45	15.6%

Section three inquires about Students' Perspectives on AI Tutoring Systems (ITAS) and encompasses the following elements: PE, EE, FC, PV, HM, HT, BI, and UB of AITS.

The research model was designed to meet research purposes by utilizing nine specific constructs. Behavioral intention (BI) and the use of behavioral artificial intelligent tutoring systems (BU of AITS) were the two constructs that were employed as affected variables in the study. Performance expectancy (PE), effort expectancy (EE), social influence (SI), hedonic motivation (HM), facilitating conditions (FC), price value (PV), and habit (HT) are seven constructs that function as independent variables. Researchers select these constructs as they facilitate the assessment of the technology in adoption and utilization (Habibi et al., 2023). The model was constructed based on eight relationships derived from the literature (Kim, 2013; Venkatesh, Thong & Xu, 2012). Figure 1 shows the relationships between the constructs and the hypotheses.

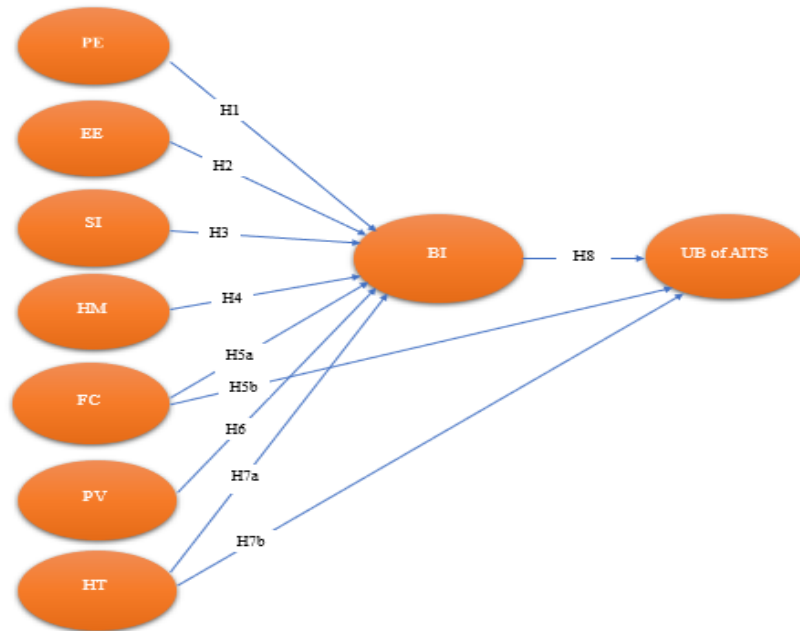


Figure 1. Adopted research model

The hypothesis proposed in the current study stated below:

H1. Performance expectancy significantly influences the behavioral intention to use AITS.

H2. Effort expectancy significantly influences the behavioral intention to use AITS. H3. Social influence significantly influences the behavioral intention to use AITS. H4. Hedonic motivation significantly influences the behavioral intention to use AITS.

H5a. Facilitating conditions significantly influence the behavioral intention.

H5b. Facilitating conditions significantly influence the use behavioral of AITS.

H6. Price value will significantly predict the use behavior of AITS.

H7a. Habit will significantly predict behavioral intention to use AITS.

H7b. Habit will significantly predict the use behavioral of AITS.

H8. Behavioral Intention significantly influences affects use behavioral of AITS during learning.

The scale was adopted from (Venkatesh, et al., 2012), consisting of nine dimensions, each containing distinct items rated on a 5-point Likert scale (estimated from 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree). Upon receiving 220 responses, the researchers downloaded all of them into an Excel spreadsheet. The subsequent phase was converting category

data into numerical data. The SPSS application facilitates the analysis of data when it is converted into numerical format. Next, preprocessing data by rejecting two responses because of incomplete data in the dataset, and twenty were eliminated because students did not use AITS at all after classifying the students by inquiring whether they utilized the software or not. Then, Data was analyzed using SPSS, and descriptive statistics; analysis of variance (ANOVA).

Normality of data distribution, reliability and validity, multiple linear regression and correlation analysis tests for the scale were used. To test the normality of data distribution. The kurtosis and skewness test are used to analyse the characteristic shape of the data distribution. Skewness values span from -2 to +2, whereas kurtosis values extend from -7 to +7 (Kim, 2013). The skewness value of PE is -.239 and the kurtosis value is -.918, and for FC -.001, -.646 respectively and so on for the other factors. which means the study data shows a normal distribution since the absolute values of skewness and kurtosis fall within the absolute value of each. Then, parametric analysis can be performed on the date. Cronbach's Alpha is employed to assess the internal consistency of the scale, yielding a value of .975 for 36 items, which indicates an excellent percentage of internal consistency. Verifying internal consistency enhances the trustworthiness of study results and guarantees that the data collection instrument is reliable and consistent (Bujang, Omar & Baharum, 2018). Multiple linear regression used to facilitate the evaluation of the relationship between a dependent variable and several independent factors, enhancing comprehension of the influence exerted by two or more independent variables on the dependent variable. also, it generates coefficients that quantify the relationship between each independent and dependent variable. Moreover, it enables researcher to discern the influence of each predictor, even while considering other variables (Alita et al., 2021). To ascertain the strength and direction of the relationship between two factors. Researchers utilize Correlation analysis tests to enhance the understanding of the interconnections among various factors.

3. Result

3.1 Person correlation

The relationship between the research model's factors is shown in Table 3, which displays the person correlation matrix. Bivariate analysis was used to find the correlation matrix. nine factors were found to be significantly related to each other based on the correlation result. which can take on values between -1 and 1, where 1 denotes a very strong positive correlation (as one variable rises, the other rise). A value of -1 denotes a very negative correlation, where one element goes up while the other goes down, while a value of 0 shows the exact opposite. Lack of association. Therefore, EE has a strong positive correlation with PE, $r=.807$, also, BI has a strong positive correlation with (PE, EE, SI, FC, HM, PV, PV, HT) as the r value for each was (0.744,0.739, 0.677, 0.74, 0.765, 0.696, 0.786) respectively.

Table 3. Pearson Correlation among factors

Factors	Mean	Std. Deviation	PE	EE	SI	FC	HM	PV	HT	BI	UB
PE	3.299	1.115	1								
EE	3.193	1.145	0.807	1							
SI	3.023	0.946	0.713	0.707	1						
FC	3.135	1.013	0.71	0.751	0.712	1					
HM	3.089	1.043	0.707	0.724	0.703	0.728	1				
PV	2.943	1.036	0.66	0.701	0.635	0.666	0.701	1			
HT	2.927	1.044	0.698	0.734	0.664	0.712	0.716	0.744	1		
BI	3.085	1.069	0.744	0.739	0.677	0.74	0.765	0.696	0.786	1	
UB	3.082	1.050	0.757	0.742	0.679	0.676	0.742	0.709	0.784	0.785	1

3.2 Multiple regression analysis

The study employed multiple linear regression analysis to assess the relationship between the dependent variable and other independent variables. The study also looked at the hypothesis to see if it supported or rejected the model and calculated coefficients to measure the relationship between an independent variable and a dependent variable. Researchers specifically examined the impact of each independent variable on the dependent variable through multiple linear regression analysis. The researchers employed a significance level of 0.05 to assess the p-values of the predictors. Variables with p-values of 0.000, 0.019, and 0.005 ($p < 0.05$) were very statistically significant and had a big effect on the dependent variable (Alita et al., 2021). The data supported this conclusion. Conversely, all variables with p-values exceeding 0.05, specifically 0.774, 0.553, 0.864, 0.480, and 0.116, did not significantly contribute to the model as they lacked statistical significance. This signifies H1, H4, H5a, H7a, H7b, and H8 support the model. Similarly, to have a significant influence on UB, the same with HM, FC, HT, and BI. However, the model was not significantly supported by H2, H3, H7b, or H6. EE, SI, PV, FC No statistically significant association exists between the dependent variable and these independent factors. Their p-values pass the 0.05 significance threshold, although their beta values remain minimal. The value for HT (H7b) is 0.405, indicating the highest standardized Beta coefficient. The dependent variable BI is most strongly impacted by variable HT, as shown in Table 4.

Table 4. Multiple regression analysis

Hypothesis	Dependent Variable	Independent Variable	Unstandardized Coefficients		Standardized Coefficients	t-statistical	p-Value
			B	Std. Error	Beta (β)		
H1	Behavioral Intention (BI)	Performance Expectance (PE)	0.178	0.062	0.186	2.859	0.005
H2		Efforts Expectance (EE)	0.039	0.065	0.041	0.594	0.553
H3		Social Influence (SI)	0.011	0.065	0.010	0.171	0.864

H4		Hedonic Motivation (HM)	0.241	0.063	0.235	3.828	0.000
H5a		Facilitating Conditions (FC)	0.154	0.065	0.146	2.366	0.019
H6		Price Value (PV)	0.042	0.060	0.041	0.708	0.480
H7a		Habit (HT)	0.324	0.064	0.316	5.092	0.000
H5b	UB of AITS	Facilitating Conditions (FC)	0.097	0.061	0.093	1.579	0.116
H7b		Habit (HT)	0.408	0.065	0.405	6.307	0.000
H8		Behavioral Intention (BI)	0.390	0.066	0.397	5.920	0.000

4. Discussions and conclusions

This is the first study to examine the determinant factors of AITS in learning by using the UTAUT2 framework. The study quantitatively investigates undergraduates' perspectives by using modified UTAUT. Among the assessed AITSs, ChatGPT emerged as the most favored. The majority of surveyed students reported utilizing AITS daily, predominantly for academic purposes. They experienced server downtime and additional issues due to AITS's unavailability. Based on the data we already have, the person correlation shows that behavioral intention (BI) is strongly linked to performance expectation (PE), effort expectation (EE), social influence (SI), facilitating conditions (FC), hedonic motivation (HM), price value (PV), and habit (HT). The analysis also considered data from consistent with prior studies (Habibi et al., 2023). Analysis of ChatGPT. Additionally, a strong positive correlation exists between EE and PE. Furthermore, the multiple regression analysis indicates that undergraduates in HE achieves superior learning outcomes and academic performance while utilizing AITS. AITS assists students in comprehending intricate concepts and achieving their educational goals. However, effort expectancy (EE) does not influence BI. Influence the Behavioral Intention (BI) to utilize EE does not determine BI to use AITS. Numerous researchers were not successful in demonstrating that EE had any influence in the UTAUT investigation (Andrews et al., 2021; Moorthy et al., 2019; Shivdas et al., 2020). Similarly, Social Influence (SI) and Price Value (PV). Furthermore, the facilitation conditions (FC) do not determine the behavioral use of the AI tutoring system (AITS) of BU. This is in contrast to the findings of previous research (Habibi et al., 2023). Habit HT serves as a robust predictor of the propensity to engage with AITS. As well as, habit HT will serve as a significant predictor of how undergraduates would utilize AITS. This explains the rate at which students utilize the AI-driven educational platform, as well as their familiarity with using AITS during learning. It is also imperative to notice that behavioral intention (BI) is a powerful factor that impacts how undergraduates use AITS while they are learning. Future researchers examining subjects akin to AITS may find this technique beneficial. The study's practical implication is the advancement of AITS. The report provides education stakeholders with guidance on enhancing the enabling conditions, which are the primary determinants of BI.

Therefore, educators must consistently highlight the importance of incorporating AI into their students' regular coursework. The current study has certain limitations that must be considered. This study relied exclusively on a survey, suggesting that alternative methods such as comprehensive interviews or group discussions could have produced comparable outcomes. Should the interviews prove to be more reliable, it will represent a significant advancement for academics engaged in this domain moving forward. The study's limitations were the reliance on one theoretical framework, quantitative approaches, universities from one region, sample size, and the fact that it only included the student perspective. Therefore, this study recommended that further research is necessary to empirically examine the factors influencing the adoption and utilization of AITS in higher education. This study focuses solely on UTAUT2, despite the potential advantages of incorporating additional frameworks such as TAM. Multiple frameworks may be employed for this type of investigation. Mixed research methodologies may yield a higher level of information. Such an approach would facilitate the comparison and enhancement of the results. In other terms, further research is necessary to validate this. The study encompassed both public and private universities in a developing country such as Iraq; incorporating universities from developed countries could enhance the sample and elucidate the rate of technology adoption. Conclusions can be derived from the current sample size; however, a bigger sample would yield results more generalizable to a wider population. Furthermore, to achieve a comprehensive understanding, the study recommended expanding students' perspectives to include teachers' perspectives too.

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Instructors' and students' perspectives on Moodle's effectiveness as a Learning Management System

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Abstract: *Learning Management System (LMS) has recently gained significant popularity. Modern learning is scientifically based and has adapted the education and learning systems accordingly. Today, the Moodle LMS platform, the most widely used in the learning process, positively impacts the learning system. As a result, the platform is utilized in both developed and developing countries. Therefore, understanding the factors affecting Moodle LMS usage is crucial. This study focuses on exploring students' and instructors' perceptions and viewpoints regarding the success of Moodle LMS in e-learning. Questionnaires were distributed to universities in Iraq that use Moodle, as well as to Near East University. The data was collected from 416 voluntary instructors and students from various universities utilizing the survey method, and statistical analysis was performed using SPSS. Regression analysis revealed variations between the quality factors that predict user satisfaction, usefulness, system use, and benefits. The dependent variable's quality factors were technical, information, service, support system, education, instructors, and learners. The results showed that two factors — technical system quality and information quality — did not support the model. Additionally, educators did not accept the instructor quality factor. Some hypotheses were supported by students' viewpoints but were rejected based on instructors' perceptions.*

Keywords: learning management system, LMS, Moodle, student perception, instructors' perception, E-learning, TAM, DeLone AND McLean.

1. Introduction

Online learning, facilitated by ICT, bridges educational gaps between educators and students and enhances virtual interactions, revolutionizing educational perspectives and system structure, making IT-based learning tools essential (Noori & Ozdamli, 2024; Mthethwa-Kunene & Maphosa, 2020; Gunawan et al., 2019). ICT-driven innovations, including personal computers, social media, broadcasting, and Learning Management Systems (LMS), have gained increasing attention in education (Sabr & Neamah, 2017). The 21st century has seen transformative changes in technology, the economy, society, and education

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(Cakrawati, 2017). Learning technology facilitates knowledge dissemination, engagement, and collaboration, enhancing learning (Gunawan et al., 2019). E-learning, an ICT-driven approach, provides access to knowledge and educational opportunities through digital platforms (Mohammed & Ozdamli, 2022; Salloum & Shaalan, 2018; Boateng et al., 2016). LMS platforms like Moodle support web-based education by enabling interaction and structured learning experiences (Munasinghe et al., 2016). Moodle is a widely used open-source LMS that enhances learning through constructivist and social learning theories (Mustapha et al., 2020). It allows instructors to effectively develop, manage, and deliver online courses, improving learning outcomes (Mthethwa-Kunene & Maphosa, 2020). Ziraba et al. (2020) identified various factors influencing Moodle's effectiveness, including social, technological, and motivational aspects.

This study examines Moodle LMS perceptions and effectiveness, incorporating DeLone and McLean Information Systems Success Model elements, assessing system success across six dimensions (Quinn & Gray, 2020). It is widely used to establish causal relationships in theoretical and applied research (Mtebe & Raphael, 2018). Technology Acceptance Model (TAM) developed by Davis (1989), TAM evaluates user technology adoption based on perceived ease of use and usefulness (Al-Fraihat et al., 2020). User Satisfaction and Learning Quality Models user satisfaction, a key determinant of e-learning success, includes perceptions of content, system performance, and instructor effectiveness (Mohammed & Ozdamli, 2022; Marjanovic et al., 2016). The Demand-Driven Learning Model (DDLML) assesses online education by analysing instructional design, content delivery, and learning outcomes (Al-Fraihat et al., 2020). Additionally, models based on Total Quality Management (TQM), ISO, and EFQM standards help measure e-learning effectiveness by balancing instructional quality, user expectations, and technological efficiency (Al Jaber, 2022). By integrating TAM with the DeLone and McLean model, this study presents a comprehensive approach to evaluating Moodle LMS, emphasizing the interplay between system quality, user satisfaction, and learning effectiveness.

2. Methods and material

A total of 426 responses were collected from Iraq and Cyprus universities. 13 incomplete responses were excluded, leaving 416 valid responses for analysis. using RAOSOFT software. The sample size was sufficient, with 174 instructors and 242 students, with a nearly equal gender distribution. The study found 370 participants from Iraq and 46 from Northern Cyprus. The questionnaire consisted of three sections: the first gathered demographic details (age, gender, occupation, and university), the second assessed LMS experience with four items, and the third explored factors affecting Moodle LMS usage through 58 elements. The study adopted the questionnaire and model developed by Al-Fraihat et al. (2020).

The research model used in this study is illustrated in Figure 1, considering technical systems, information, services, educational systems, supporting systems, learners, and instructors and related hypothesis.

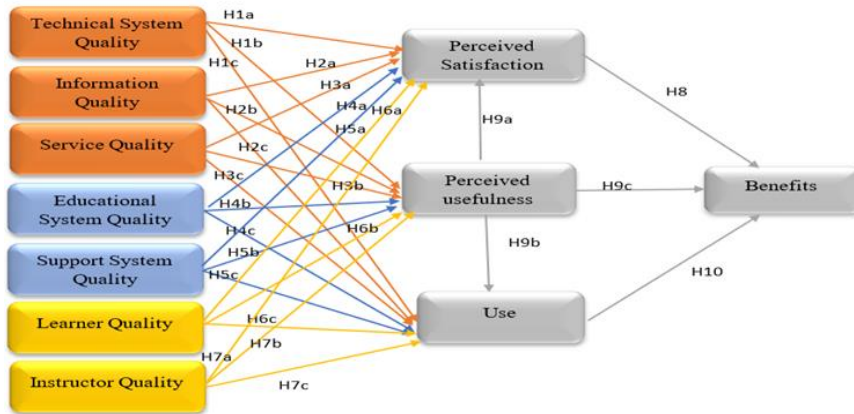


Figure 1. An adopted model for this study

The study assessed users' experience with Moodle and other learning management platforms. Four questions were asked to teachers and students, with students having the most experience (68.2%), followed by 1-2 years (22.3%) and 3-5 years (7.9%). Only 1.6% used Moodle for more than six years, as shown in Figure 2.

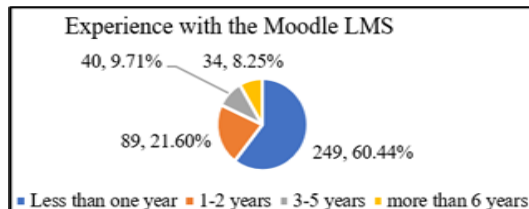


Figure 2. Experience with Moodle LMS

The majority of 174 teachers (48.3%) reported using Moodle for less than one year, followed by 1-2 years (20.1%), 3-5 years (14.4%), and over six years (17.2%), as shown in Figure 3.

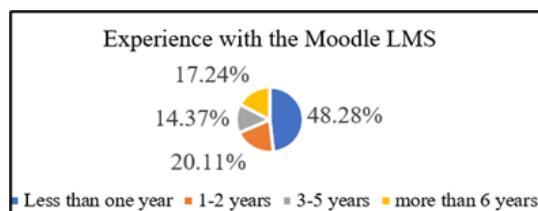


Figure 3. Instructors' experience with Moodle LMS

The survey revealed that 32.2% of 242 student respondents used Google Classroom, followed by Edmodo (20.2%), Moodle (19%), and Blackboard

Learning (11.6%). Moodle was the most commonly used LMS by 74.7% of 174 as shown in Figure 4.

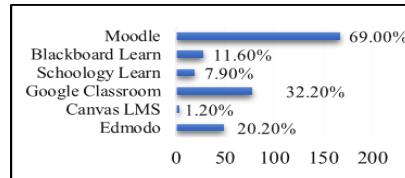


Figure 4. Students using LMS platforms

instructors, followed by Edmodo (23%), Blackboard Learning (18.4%), and Schoology (12.1%). As shown in figure 5.

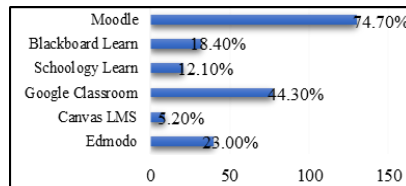


Figure 5. Instructors using LMS platforms

The study analyzed seven key factors influencing the success of the Moodle Learning Management System (LMS), obtained ethical approval from the University's Ethical Committee for Science Study, and used a questionnaire with 11 dimensions and a 5-point Likert scale. The structured approach ensured reliability and participant evaluation. The structured approach ensured reliability and participant evaluation, with a Cronbach's alpha (α) of 0.988, exceeding the recommended threshold (Al-Fraihat et al., 2020).

The study used descriptive statistics to analyze demographics and ANOVA to test the model's significance. A linear regression analysis was used to evaluate hypotheses. A validated questionnaire was identified, and ethical approval was obtained. A Google Form survey was used for data collection. The study followed a structured process outlined in Figure 6.

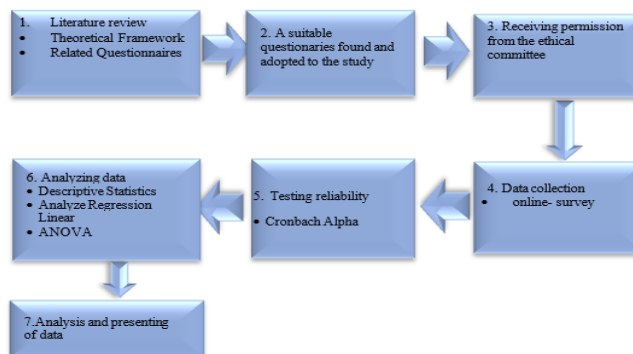


Figure 6. The research procedure

3. Result and discussion

3.1 Correlations among the critical factors

Table 1 shows the correlation matrix indicating the connection between the structure of the research model. The correlation matrix was found using bivariate analysis. The correlation result identified eleven critical factors significantly associated with each other. Consequently, the design was supposed to be convenient for regression analysis.

Table 1. Validity correlation matrix of eleven critical factors of the study

	BN	SU	PUSF	PSAT	IQ	LQ	SSQ	ESQ	SQ	INQ	TSQ
students' validity perceptions											
BN	1										
SU	0.881	1									
PUSF	0.878	0.869	1								
PSAT	0.877	0.86	0.883	1							
IQ	0.857	0.871	0.877	0.879	1						
LQ	0.841	0.831	0.854	0.869	0.896	1					
SSQ	0.838	0.808	0.832	0.847	0.869	0.85	1				
ESQ	0.851	0.804	0.836	0.846	0.861	0.86	0.874	1			
SQ	0.828	0.774	0.766	0.803	0.802	0.79	0.85	0.84	1		
INQ	0.817	0.771	0.782	0.806	0.829	0.81	0.818	0.85	0.859	1	
TSQ	0.874	0.852	0.856	0.856	0.875	0.87	0.866	0.9	0.862	0.911	1
Instructors' validity perceptions											
BN	1										
SU	0.724	1									
PUSF	0.71	0.658	1								
PSAT	0.775	0.744	0.795	1							
IQ	0.752	0.725	0.71	0.762	1						
LQ	0.709	0.63	0.695	0.737	0.757	1					
SSQ	0.636	0.661	0.553	0.639	0.671	0.67	1				
ESQ	0.671	0.589	0.61	0.652	0.698	0.71	0.699	1			
SQ	0.646	0.671	0.693	0.697	0.677	0.69	0.665	0.65	1		
INQ	0.631	0.596	0.652	0.721	0.69	0.61	0.631	0.64	0.703	1	
TSQ	0.703	0.653	0.698	0.752	0.708	0.68	0.654	0.66	0.693	0.791	1

3.2 Hypothesis testing

The study's results, obtained through multiple regression analysis, are presented in Table 2. The framework, based on the findings of the Analysis of Variance (ANOVA), was found to be significant ($p < 0.05$). The input technique was used to determine which predictors — technical system quality, information quality, service quality, educational system quality, support system quality, learner quality, and instructor quality — affect the dependent variables: perceived satisfaction, usefulness, system use, and benefits.

Table 2. Hypothesis testing and path analysis result for influence factors on moodle LMS

Dependent variable: Students' Perceptions Towards Using Moodle LMS							
Hypothesis	Path	Unstandardized Coefficients		Standardized coefficients	T-Statistical	P-Value	Support
		B	Std. Error	β Coefficients			
H1a	TSQ → PSAT	.070	.133	.856	.523	.601	Not support
H1b	TSQ → PUSF	.083	.134	.856	.617	.538	Not support
H1c	TSQ → SU	.094	.133	.852	.707	.480	Not support
H2a	INQ → PSAT	.110	.159	.806	.692	.490	Not support
H2b	INQ → PUSF	.218	.169	.782	1.291	.198	Not Support
H2c	INQ → SU	.255	.168	.771	1.513	.132	Not support
H3a	SQ → PSAT	.442	.145	.803	3.041	.003	Support
H3b	SQ → PUSF	.593	.158	.766	3.749	.000	Support
H3c	SQ → USE	.549	.152	.774	3.612	.000	Support
H4a	ESQ → PSAT	.298	.129	.846	2.308	.022	Support
H4b	ESQ → PUSF	.352	.134	.836	2.619	.009	Support
H4c	ESQ → SU	.456	.142	.804	3.204	.002	Support
H5a	SSQ → PSAT	.331	.128	.847	2.591	.010	Support
H5b	SSQ → PUSF	.399	.134	.832	2.974	.003	Support
H5c	SSQ → SU	.475	.140	.808	3.404	.001	Support
H6a	LEQ → PSAT	.354	.116	.869	3.064	.002	Support
H6b	LEQ → PUSF	.421	.122	.854	3.438	.001	Support
H6c	LEQ → SU	.486	.128	.831	3.805	.000	Support
H7a	IQ → PSAT	.252	.114	.879	2.223	.027	Support
H7b	IQ → PUSF	.273	.115	.877	2.368	.019	Support
H7c	IQ → SU	.287	.115	.871	2.488	.014	Support
H8	PSAT → BN	.439	.108	.877	4.502	.000	Support
H9a	PSUF → PSAT	.381	.107	.883	3.549	.000	Support
H9b	PSUF → SU	.429	.111	.869	3.868	.000	Support
H9c	PSUF → BN	.424	.108	.878	3.922	.000	Support
H10	SU → BN	.418	.107	.881	3.896	.000	Support

Table 3. Hypothesis testing and path analysis result for influence factors on moodle LMS

Dependent variable: Instructors' Perceptions Towards Using Moodle LMS							
Hypothesis	Path	Unstandardized Coefficients		Standardized coefficients	T-Statistical	P-Value	Decision
		B	Std. Error	β Coefficients			
H1a	TSQ \rightarrow PSAT	.410	.224	.752	1.834	.068	Not Support
H1b	TSQ \rightarrow PUSF	.473	.257	.698	1.843	.067	Not Support
H1c	TSQ \rightarrow SU	.468	.276	.653	1.694	.092	Not Support
H2a	INQ \rightarrow PSAT	.141	.264	.721	.535	.593	Not support
H2b	INQ \rightarrow PUSF	.300	.305	.652	.981	.328	Not Support
H2c	INQ \rightarrow SU	.377	.329	.596	1.146	.253	Not support
H3a	SQ \rightarrow PSAT	.617	.242	.702	2.545	.012	Support
H3b	SQ \rightarrow PUSF	.420	.254	.707	1.651	.101	Not Support
H3c	SQ \rightarrow USE	.336	.269	.678	1.250	.213	Not Support
H4a	ESQ \rightarrow PSAT	.722	.252	.675	2.865	.005	Support
H4b	ESQ \rightarrow PUSF	.774	.281	.628	2.754	.007	Support
H4c	ESQ \rightarrow SU	.715	.295	.595	2.425	.016	Support
H5a	SSQ \rightarrow PSAT	1.033	.244	.647	4.233	.000	Support
H5b	SSQ \rightarrow PUSF	1.269	.281	.558	4.520	.000	Support
H5c	SSQ \rightarrow SU	.587	.256	.666	2.290	.023	Support
H6a	LEQ \rightarrow PSAT	.437	.222	.751	1.964	.051	Not Support
H6b	LEQ \rightarrow PUSF	.465	.253	.705	1.841	.068	Not Support
H6c	LEQ \rightarrow SU	.587	.281	.632	2.092	.038	Support
H7a	IQ \rightarrow PSAT	.268	.224	.765	1.196	.223	Not Support
H7b	IQ \rightarrow PUSF	.331	.259	.710	1.279	.203	Not Support
H7c	IQ \rightarrow SU	.043	.252	.725	.170	.865	Not Support
H8	PSAT \rightarrow BN	.992	.173	.779	5.722	.000	Support
H9a	PSUF \rightarrow PSAT	.912	.166	.796	5.490	.000	Support
H9b	PSUF \rightarrow SU	1.063	.222	.657	4.787	.000	Support
H9c	PSUF \rightarrow BN	1.379	.186	.708	7.433	.000	Support
H10	SU \rightarrow BN	1.474	.171	.723	8.613	.000	Support

The impact of Technical System Quality (TSQ) on perceived satisfaction, usefulness, and system use in the e-learning system was analyzed. From students' perspectives, TSQ did not significantly influence perceived satisfaction (H1a: $\beta = .856$, $t = .523$, $p = .601$), perceived usefulness (H1b: $\beta = .856$, $t = .617$, $p = .538$), or system use (H1c: $\beta = .852$, $t = .707$, $p = .480$), as shown in Table 2. Similarly, from instructors' perspectives, TSQ showed no significant effect on perceived satisfaction, perceived usefulness, or system use, as indicated in Table 3. Since the p-values were more significant than 0.05 ($p > 0.05$) for both students and instructors, TSQ did not support the model. However, the result for H1a aligns with findings from Yakubu and Dasuki (2018), and a similar effect for H1c was observed in previous studies (Aparicio et al., 2017; Cidral et al., 2018). Influence of Information Quality on Perceived Satisfaction (PSAT), Perceived Usefulness

(PUSF), and System Use (SU) in the E-Learning System As shown in Tables 4 and 5, both teachers and students rejected Information Quality (INQ) after hypothesis testing. From students' perspectives, INQ did not significantly influence PUSF, or SU Similarly, instructors' perceptions also showed no significant impact on PSAT or PUSF, H1a, H2b with p-values exceeding 0.05. The result for H2a aligns with Lwoga (2014), while H2c supports findings by Al-Fraihat et al. (2020). These findings suggest that providing high-quality information does not necessarily impact students' usage of the e-learning system. One possible explanation is that students primarily rely on the system to access the Moodle Reading Capture resource and submit assignments electronically (Al-Fraihat et al., 2020).

Influence of Service Quality on Perceived Satisfaction (PSAT), Perceived Usefulness (PUSF), and System Use (SU) in the E-Learning System The statistical analysis indicates a positive correlation between service quality and perceived satisfaction from both educators' and students' perspectives. The coefficient for H3a shows significant support for students and educators with p-values less than 0.05, as shown in Table 2. This finding aligns with previous research (Mtebe & Raphael, 2018). However, for H3b and H3c, the results differ between students and instructors. While students accepted both hypotheses H3b, and H3c. Instructors rejected them. As shown in Table 3, the p-values for instructors were greater than 0.05, indicating no significant impact from their perspective. As shown in Table 2. Influence of Educational System Quality on Perceived Satisfaction (PSAT), Perceived Usefulness (PUSF), and System Use (SU) in the E-Learning System. The impact of Educational System Quality (ESQ) on PSAT (H4a) received significant support from both students and instructors. The hypothesis was accepted with students' responses and instructors' responses, with p-values less than 0.05. These findings align with Mohammadi (2015). However, for H4b (ESQ → PUSF) and H4c (ESQ → SU), the results differed between students and instructors. Students supported both hypotheses (H4b and H4c) while instructors rejected them. The p-values for instructors in H4b and H4c were greater than 0.05, indicating that ESQ did not significantly influence their perception of usefulness and system use. Influences of Support System Quality on PSAT, PUSF, and SU with the e-learning system: The expectation of influencing the support system quality on three dependent variables was significant, as can be seen in Table 2 and Table 3. Instructors and students have accepted all hypotheses, and the p-values are less than (0.05). Hence, all suggestions support the system model. As the from response students' for H5a and H5b; PUSF, then H5c for SU ($\beta=.808$, $t=3.404$, $p=.001$). On the other side, from instructors' responses are same, this finding parallels the result of (Alfaki, 2021). Influences of learner's quality on PSAT, PUSF, and SU with the e-learning system: Table 2 shows that hypotheses H6a and H6b have two different reactions as students accept both. For instructors, the viewpoint is rejected. While from instructors' response PSAT and PSUF the p-value for instructors' response is greater than (0.05). Nevertheless, for H6c, a similar reaction is shown for students and instructors, as has been accepted. After testing the hypothesis, the p-value of p is less than (0.05). Consequently, the impact

of learners' quality on System use is significant, and it supports the model — the finding result for H6c supports other study (Mohammadi, 2015).

Influences of instructor's quality on PSAT, PUSF, and SU with the e-learning system: The statistical analysis result shows the optimistic finding in students' responses as the student accepts the H7a, H7b, and H7c. The instructor is the main person who is essential to students in the e-learning environment (Al-Fraihat et al., 2020). Therefore, instructor quality positively impacts learners' satisfaction with E-learning. Hypothesis H7a was accepted and H7b, which is predicted to impact the perceived usefulness and H7c for SU. As shown, the value of p is less than (0.05). So, in the student's opinion, the instructor's quality supports the model. Moreover, the finding of testing hypotheses is like the study outcome (Al-Fraihat et al., 2020). While the results from instructors' responses were pessimistic, all hypotheses do not support the model from the instructors' viewpoint, H7 and H7b. The hypotheses are insignificant if the p -value is more than (0.05). Al-Fraihat et al. (2020) for H7c explained that a potential explanation for this insufficient relationship might be that students depend on Moodle to access the tools teachers upload and send assignments using the online submission method. Consequently, factors relating to teachers were closely linked to their perceived satisfaction and usability of the program but not to their usage of it.

Influences of Perceived Satisfaction on Benefits with the E-learning System: Hypothesis H8 was predicted to impact the benefits of online learning. Which ($P < 0.05$) represents that the perceived satisfaction has significantly influenced benefits and has been accepted by students and instructors. Therefore, the hypothesis supports the model. A similar study was found by other researchers (Aparicio et al., 2017; Cidral et al., 2018). Influences of Perceived Usefulness on PSAT, PSUF, and BN with the e-learning system: Predicting hypotheses related to perceived usefulness has significantly supported the model. As H9a, H9b, and H9c are accepted by both learners and educators. The positive result is that perceived usefulness is a critical determinant of instructors'/students' perceived usefulness, satisfaction, and system use. Students should be fulfilled because they find that the program increases their academic success and behaviours, allows them to complete their assignments quickly and efficiently with less energy, and thus succeed more efficiently (Al-Fraihat et al., 2020). The p -value ($p < 0.05$) for H9a, H9b and H9c from students' perception. Likewise ($p < 0.05$), H9a, H9b and H9c from instructors' perception. The hypothesis results parallel the findings of (Al-Fraihat et al., 2020; Lwoga, 2014). From the above, it has become clear that if students and lecturers believe that the e-learning system improves the learning process, helping them to perform their duties quickly and effectively with less effort and benefit, they will be motivated to use it. Influences of the use of benefits with the e-learning system: Despite the reality that advantages are gained when students use learning Processes and systems (Al-Fraihat et al., 2020). The model's last dimension is that teachers and students have accepted SU. As the hypotheses, H10 is associated with using the e-learning system and its effects on student benefits. The student's perspective

and the viewpoint of instructors, the p-value less than (0.05), the testing hypothesis indicating that the system user has a significant positive impact on benefits, and it supports the model. Consequently, the effect of System use is substantial, and it supports the model. The findings support the results obtained by researchers (Cidral et al., 2018).

4. Conclusion and recommendation

The Moodle Learning Management System (LMS) is an essential platform for online learning, enhancing learner independence and facilitating efficient resource management. A study examined students' and instructors' perceptions of Moodle LMS and its effectiveness using various models. Survey findings showed that most users have less than a year of experience, with Moodle, Google Classroom, and Edmodo being the most frequently used LMS platforms. Enhancing service quality, educational system quality, support system quality, learner quality, and instructor quality directly increases students' satisfaction and engagement with e-learning platforms. Future studies should include a broader range of institutions for a more comprehensive evaluation.

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Opportunities and satisfactions of higher education students towards online assessment

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Abstract: *With the use of online and virtual learning platforms, traditional evaluation methods have become obsolete. For this reason, online assessment and formative assessment approaches are becoming more popular. For this reason, this study aimed to determine higher education students' opportunities and satisfaction levels regarding online assessment. 285 undergraduate and graduate students participated in the study. The method of the research is a descriptive study. According to the results obtained from the study, students' opinions about online assessment opportunities are positive. At the same time, a significant difference was detected in favour of graduate students according to education level. These findings show that students are open to using online assessment tools and that they can offer useful evaluation options for higher education. The study emphasizes that more research is necessary to improve educational results using online evaluation tools, particularly for graduate-level students.*

Keywords: Online Assessment, Formative Assessment, Higher Education, Opportunities.

1. Introduction

Learning assessment provides teachers and students with constant feedback and teaches students to reason and think instead of merely obeying directions. However, the formative assessment tool adoption rate is low due to a lack of a clear understanding of the tool. Educators and policymakers play a crucial role in educating others about these tools (Musa & Islam, 2020).

There are always some gaps in formative assessment for learning that need to be addressed in the academic sector. One approach to inspiring and motivating is to explore the possibilities of certain formative assessment techniques used during the pandemic and possibly in the future. The significance of online learning for educational innovations is growing and achieving a balance between the accuracy

and usability of formative assessment technologies will require extensive research in the long run.

Despite its few challenges, formative assessment research is of paramount importance, as its benefits are widely acknowledged (Bhagat & Spector, 2017). This research is integral to developing and improving our educational systems, making educators and policymakers key players in the process.

One challenge is figuring out how formative exams affect students' understanding of the best times and methods for administering them. Whether a formative assessment influences learning more than other factors is another issue rarely the subject of controlled research. A student may begin to generate self-evaluations that mimic the kind of formative feedback thought to be most beneficial for learning advancements. Such a desirable and measured metacognitive learning outcome aligns with self-regulated learning (Butler & Winne, 1995).

It may not be enough to evaluate the effectiveness of teaching methods in the learning process only with academic performance or measurable outcomes. Students' perceptions provide effective feedback on how they experience the process. In addition, how students approach the teaching method or assessment processes can directly affect their active participation. Negative perceptions can cause a decrease in student motivation (Pintrich & De Groot, 1990). The learning process can be effectively organized when it is evaluated not only with academic success measurements but also with how students perceive their learning experiences (Ramsden, 2003). For these reasons, analyzing perceptions helps to understand the applicability and sustainability of the learning method. It may be meaningful to analyze student perceptions without conducting an experimental study. Student perceptions supported by quantitative data are an important preliminary research that can prepare the ground for future experimental studies.

Within this general framework, understanding students' perceived learning opportunities for online assessment methods is an important area of research. Therefore, the following questions arise:

- What are higher education students' perceptions of online assessment opportunities?
- What are the students' satisfaction levels with formative assessment tools?

1.1 Related research

Bezerra (2020) focuses on integrating information technology tools in universities and their impact on teaching methods. The researcher emphasizes that the availability of these technologies in face-to-face and distance education can potentially change teacher-student interactions. Incorporating ICT into the curriculum is a way to develop and promote new education methods. This

increases the demand for continuing education and opens up innovations in research and teaching (Bezerra, 2020). Guilding et al. (2020) found that online formative assessments and active learning improved student learning outcomes. Students reported that answering questions was the most effective way to fill knowledge gaps and strengthen exam skills (Guilding et al., 2021).

Frost et al. (2021) emphasized that formative assessment helps students understand their mistakes and prevent future errors. Furthermore, the best approach to evaluate learning is performance-based since it shows how successfully students apply the knowledge, abilities, and skills they have just acquired (Frost, Matta & Kenyo, 2021; Jacob, 2020). A study conducted in 2020 by Baig et al. found that students and instructors are becoming more accustomed to learning management systems (LMS). Online and traditional in-person training are combined in blended learning. LMS is used all over the world. One of the most important examples of a virtual learning environment is Blackboard, a particularly designed course management system and e-learning platform. Among other things, it distributes and arranges homework and provides online exams. In Çekiç and Bakla's (2021) study, it was stated that digital formative assessment methods positively affect educational processes by using them together with traditional methods. Socrative, Plickers, Kahoot, Google Forms, Google Forms, Quizzes and Nearpod are among the most commonly used technologies in the study (Çekiç & Bakla, 2021). These technologies increase student motivation and engagement by creating gamification and interactive classroom environments. Teachers are encouraged to use these tools that integrate assessment with education.

The purpose of Yenmez and Gökçe's study in 2021 was to evaluate the effect of Web 2.0 technologies used for measurement and evaluation purposes in virtual learning. It has been stated that gamification applications such as Quizizz, Kahoot and Socrative, as formative assessment tools, have an indisputable benefit regarding the exam result (Yenmez & Gokce, 2021). In traditional learning environments, the teacher determines the level of the learners throughout the learning process, what the goals are, and what needs to be done to achieve these goals (Yarahmadzahi, N., & Goodarzi, 2019). The teacher is responsible for the tasks of designing and implementing a successful learning environment.

The establishment and exploitation of instructional contingency situations for the goal of regulating learning processes are important to formative assessment (Wiliam & Thompson, 2017). It's a crucial component of a teacher's work in the classroom and paying attention to developing one's methods will boost students' accomplishments. In the formative assessment process, the teacher must design activities that will encourage learners to think more. In addition, learners are expected to actively participate in the learning process (Black & Wiliam, 1998).

Black & Wiliam (2003) stated in their study that formative assessment processes have achieved successful results in different subject areas, at different levels of education, and with different types of knowledge and skills. The study

also determined that student scores, especially for students who may be less talented, do not have much effect on formative assessment processes, but the quality of feedback is an important factor.

Learners should be guided on how to use feedback from teachers, the qualities of the projects they produce, and approaches on how to improve these qualities. It cannot be assumed that learners understand what they need to do after feedback is given (Sadler, 1998). The main purpose of formative assessment processes is to improve learning processes (Wijesoorya, Heales & Clutterbuck, 2015).

Rawekar et al., in their study investigating the effect of formative assessment practices for students in graduate institutions, stated that students' scores increased after the application. For this reason, it can be said that formative assessments are valid, acceptable and efficient for graduate students (Rawekar et al., 2020).

2. Methodology

This descriptive study was conducted to determine higher education students' opinions and satisfaction levels regarding online assessment methods and formative assessment tools.

2.1 Participants

Near East University undergraduate and graduate students (n=285) participated in the study. 44.9% of the participants were females, and 55% were males. In addition, when we look at the students' education level, 58.9% are undergraduate students, and 41.1% are graduate students.

2.2 Data collection tools

The data collection tool consists of 3 sections. The first part includes questions about demographic information. In the second part, there are questions to determine university students' satisfaction with the online formative assessment tools they have used. In the last part of the data collection tool, the digital natives' opinion scale for online assessment was developed by (Ndibalema, 2021). The original scale consists of a 4-point Likert scale and ten items. In this study, the 10-item scale was used as a 5-point Likert scale. Likert-type scale from Strongly Agree (5 points), Agree (4 points), Neutral (3 points), Disagree (2 points) and Strongly Disagree (1 point). Cronbach's Alpha analysis was performed on all ten items to determine the scale's reliability; as a result, it was defined as .903. This result shows us that the results obtained are reliable.

2.3 Data analysis

While frequency, mean, and independent sample t-test analyses were used to analyze quantitative data, open-ended questions were analyzed using an in-depth analysis technique.

3. Results

3.1 Higher education students' opinions on online assessments

The results obtained from the analyses conducted to determine the opinions of higher education students on online assessment are presented in the table below.

Table 1. Opinions towards online assessment opportunities

Items	Mean	SD
"Online assessment enhances my thinking beyond the four walls of learning"	3.66	.765
"The online assessment offers the possibility of self-checking on the current level of knowledge, which motivates me to work further"	3.72	.685
"Immediate results obtained upon test completion are motivating for further learning"	3.81	.687
"Online assessment offers the possibility of verifying errors and making corrections at any time to fill in my knowledge gaps"	3.74	.788
"Online assessment provides instructors with immediate feedback to improve my learning"	3.77	.432
"Online assessment provides an unbiased grading, which improves my learning process"	4.09	.765
"Online assessment of self-learning and problem-solving skills"	3.74	.342
"Online assessment improves my technological technical skills"	3.82	.234
"Online assessment is appropriate for learning for all students and those with disability"	3.63	.123
"System feedback helps me to reflect on my merits in learning"	3.75	.543
General opinions of students towards online assessment	3.77	.656

According to the findings obtained from the analysis, students agree with the statement, "Online assessment provides unbiased grading, which improves my learning process." Higher education students rated the statement, "Online assessment is appropriate for learning for all students and those with disabilities," the lowest within the limits of agreement.

Higher education students' overall opinions about the possibilities of online assessment are also positive.

3.2 Comparison of higher education students' views on online assessments according to education level

The findings obtained from the analyses conducted to determine the opinions of undergraduate and graduate students towards online instructors are presented in the table below.

Table 2. Online assessment opportunities opinions of students according to education level

Relationship variable	N	Mean	SD	Mean difference	t	P
Undergraduate	168	3,667	.873	.2688	2.671	.008
Graduate	117	3,936	.779			

According to the results obtained from the independent sample t-test analysis, graduate students' views on the opportunities of online instructors were more positive than those of undergraduate students. This may be because graduate students have more academic experience than undergraduate students, which helps them understand the advantages better. In addition, graduate students may have used online environments more in their learning process and gained more experience. Therefore, they may have evaluated online assessment opportunities more positively.

3.4 Higher education students' satisfaction levels towards formative assessment tools

The results from the research satisfaction with the tools they use in their learning processes are presented in the table below.

Table 3. Satisfaction levels of students towards formative assessment tools

Formative Assessment Tools	Mean	SD
Peergrade	3,46	,785
EdPuzzle	3,38	,816
Quizlet	3,71	,906
Google Forms	3,85	,922
Google Classroom	3,72	,931
Nearpod	3,45	,857
Kahoot	3,41	,890

According to the results, students are generally satisfied with the tools used in formative assessment processes. Google Forms and Google Classroom were the tools with which they expressed the most satisfaction. Their satisfaction levels may be high because the user-friendly interfaces of Google tools do not require technical knowledge and skills, preventing them from encountering difficulties. In addition, many of the Google tools are used in many educational institutions and students may be familiar with these tools in their previous learning processes.

4. Discussions and conclusions

The study's results show that higher education students' opinions on online assessment and formative assessment tools are generally positive.

Students stated that online assessments help them develop their thinking skills, allow them to check their knowledge level, provide instant feedback, increase motivation, and provide more learning opportunities. Opportunities such as unbiased grading were also found to be important factors.

Satisfaction with formative assessment tools was generally positive for all tools. However, more work is needed on the accessibility and inclusiveness of online assessments. Educational institutions must make more efforts to ensure that formative assessment platforms are accessible and fair for all students.

Moreover, graduate students' more positive opinions of online assessments may be attributed to their academic experience and familiarity with online tools. This finding suggests that as the level of education increases, online assessments may be adopted and evaluated more positively. These results indicate that higher education institutions should consider student groups' different needs and experiences when designing online assessment systems.

In conclusion, educational institutions should continue to improve the use and accessibility of online assessment tools to increase student satisfaction and make learning processes more efficient.

As with every study, this study has some limitations. Some of them are that it is limited to a certain group of students and the statements in the scale. In future studies, it is aimed to be carried out with different research methods to a wider audience.

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Model for rapid assessment of engagement in academic courses using genetic algorithms

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Abstract: *This paper presents a model for rapid assessment of fundamental notions from an academic course and its implementation using the Python language. The model has two types of users: professor and student. The professor can enter test items along with answer options, and students must respond in a limited time to a test generated using genetic algorithms. The items are stored in a database to be used as a starting point for the test generator. To avoid the similarity of the tests, the items and answer options are permuted, thus obtaining results that correctly and impartially reflect the engagement in the course.*

Keywords: algorithm, learning, test, modelling, database, interfaces.

1. Introduction

In the current conditions, great emphasis is placed on students' attention to courses. Thus, considering the means of communication such as mobile phones, tablets, laptops that can become means of disrupting attention to courses, the problem arises of motivating students to actively participate, engage in the course and acquire minimal knowledge. In this sense, rapid tests can be a solution to solve this problem.

In order to spend as little time as possible in order to design and implement time these tests, a rapid mechanism is also needed for this. Testing can be done either through mobile devices or through other devices that have access to the Internet. In addition, the way the tests are composed must consider the limited response time. This problem can be solved by using items with multiple-choice answers.

The model that we will present in the following sections contains a mechanism for entering items and answer options into a database along with a list of courses in which they can be used (courses are numbered with consecutive numbers: 1, 2, 3, ...). Another component of the model is the selection of items to obtain a test by the professor. The created test is then transformed with genetic algorithms into as many tests as there are students by permuting the items and

2. Model presentation

The model will have three main components:

- Items
- Eval
- Verif

The first component **Items** presented in figure 1, contains a mechanism for the insertion of items within a database. The items have several components, such as the statement, the answer choices (a common item format such as single-answer Multiple-Choice Question – MCQ – was used, with 4 choices and one of them being the correct answer) and a list of courses that can be used for assessment (1, 2, 3, ...), as well as a mechanism for selecting from the database the items preferred by the professor for the assessment and building the assessment test specific to the current course. By using a genetic algorithm for selecting the items and permutating the answer choices, a number of tests equal to the maximum number of students who can be present at the course is created.

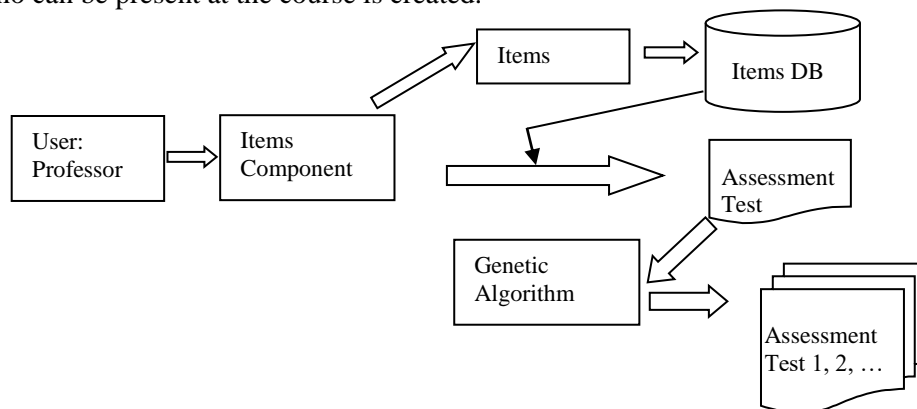


Figure 2. The Items component in the model

The second component, **Eval**, is the assessment component, shown in Figure 3, in which the student logs in and receives the test, selects the choices they consider correct and submits them to a database with answers.

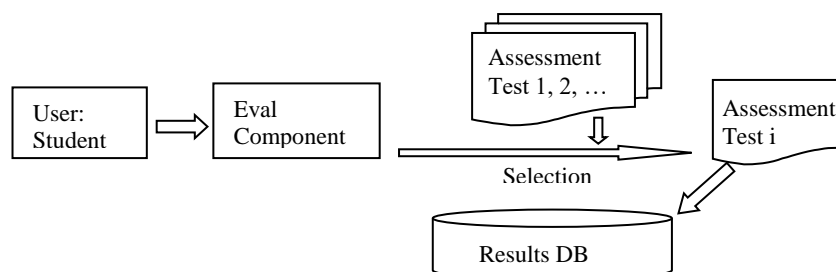


Figure 3. Eval component in the model

The third component, **Verif**, is managed by the professor, shown in Figure 4, to transmit the answers to the students and to produce various useful statistics for the courses to follow.

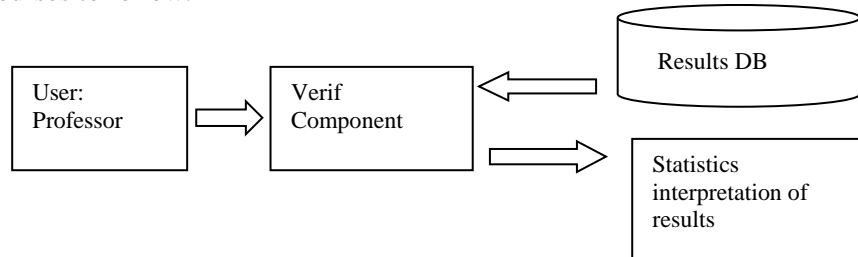


Figure 4. Verif component in the model

The three components of the presented model can be integrated into a web or mobile platform to obtain a complex application with many e-learning features, such as those in (Popescu et al., 2023), (Hamidi et al., 2011) and (Popescu et al., 2021a).

3. Implementation

In order to assess the efficiency of the model, several aspects of the model were implemented using a Python-based implementation, especially related to the assessment test generation. For the other aspects of the model, such as Eval and Verif, a separate implementation was used.

In order to determine the efficiency of the Items component, a Python implementation was made, with a number of 1000 ($n = 1000$) of items established in the database. The numeric measurement of the fastness and the variety characteristics of the algorithm was determined using a specific form of the fitness function. The form of the fitness function is shown in Equation (1).

$$f = w_1 \times E_T + w_2 \times M_T \quad (1)$$

where:

- E_T is the total entropy of the test, where the entropy measures the total measurement of the permutation of the choices of all items. The entropy of each item is the total number of inversions made to the choices reported to the total number of the possible inversions of all choices of the item. This entropy is calculated based on the permutation of the choices and using permutation-based computations. Thus, given an item q_i and its set of choices $V = \{v_1, v_2, \dots, v_l\}$, with l being the total number of choices, an initial order of choices $O = (v_1, v_2, \dots, v_l)$ and a permutation of the order $P = (v_{\pi(1)}, v_{\pi(2)}, \dots, v_{\pi(l)})$, where π is a permutation of the indices $\{1, 2, \dots, l\}$, an inversion is considered made when two choices (v_j, v_k) exist such $j < k$ and $\pi(j) > \pi(k)$. Thus, the number of inversions made for an item q_i (I_i) and the total number of possible inversions (I_{max}) can be determined with the next relations:

$$I_i = \sum_{1 \leq j \leq k \leq v} 1(\pi(j) \neq \pi(k)) \quad \text{and} \quad I_{max} = \frac{l \times (l - 1)}{2} ,$$

where $I(\text{condition})$ is an indicator function which has the value 1 if the condition is true and 0 otherwise. This part of the fitness function determines the tests whose items are the most different from the initial items extracted from the database after the choices of the test items are permuted (item choice variation):

$$E_T = \frac{1}{m} \sum_{i=1}^m E_{q_i} , \quad E_{q_i} = \frac{I_i}{I_{max}}$$

For example, for an item with $l = 4$ choices with the initial order $O = (A, B, C, D)$ and the permutation $P = (C, A, D, B)$, the original indexation would be $A = 1, B = 2, C = 3$ and $D = 4$ and the permutation is indexed as $P = (3, 1, 4, 2)$. Each pair is then verified (e.g., (A, C) is considered inversion because C is after A in the permutation). The number of inversions I_i and I_{max} are then computed using the described relations, resulting a total entropy of the item being equal to $4 / 6$ (0.67). Another version of inversions may be considered when a choice is set on a different index than the original one. This case will be treated in future research papers.

- M_T is the normalized value of the difference between the value of the calculated total time of the test and the time desired and given by the user (T_G). This part of the fitness function determines the closest tests to a given time by the user (time restriction).

$$M_T = 1 - \frac{|T_G - T|}{T_G} , \quad T = \sum_{i=1}^m t_{q_i}$$

- w_1 and w_2 are the weights of the two parts of the fitness function and help the user to obtain tests giving greater importance either to item choice variation or time restriction, w_1, w_2 in $[0,1]$. The weights are used to give equal or different importances to the two parts of the fitness function (e.g., if the user desires the generation of a test with items which would have a greater degree of permutation, the choices being more disordered than the original order, then w_1 would have a greater value; if the user desires a test that would have a solving time closer to a given one, then w_2 would have a greater value).

Using this function, the user can obtain tests considering the two main important characteristics of the test: choice variety and total solving time. Using this form of the fitness function, the implementation was built and several trials for the parameters of the generation mechanism of the component Items were made. Firstly, the interface of the implementation of the Items components is shown in Figure 5.

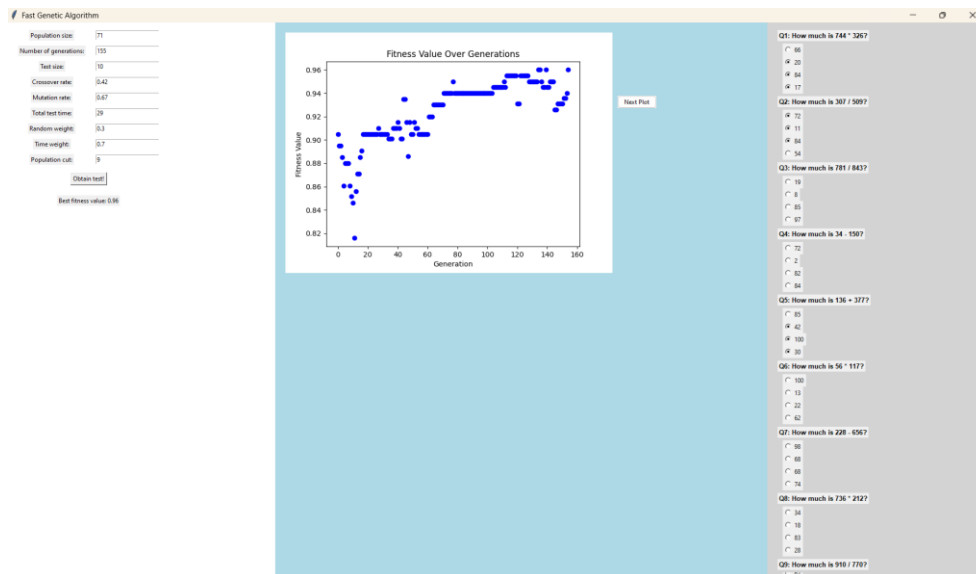


Figure 5. The implementation of the Items component

There were four characteristic that were studied for the efficiency of the generation mechanism: (1) convergence; (2) robustness; (3) performance for various parameter values; and (4) fitness distribution.

Firstly, the convergence of the algorithm was determined. For that, the genetic algorithm was run for a random set of parameters:

- the size of initial population (NP) is 71;
- the number of generations (NG) is 155;
- the number of items in the test (m) is 10;
- the crossover rate (rc) is 0.42;
- the mutation rate (rm) is 0.67;
- the total test time (TG) is 29 minutes;
- the values of w_1 and w_2 , as they are explained above, are 0.3 and 0.7; these values have the meaning that the user desires a test that would respect to a greater extent the desired solving time opposing to the entropy (disorder) of the choices of the items that form the test; the choice of the value was randomly set;
- the number of the best individuals selected at each generation (S) is 9.

For a single run of the genetic algorithm, the best fitness value for this is 0.96, while fitness values are comprised between 0 and 1. The values of the fitness function were calculated after each generation, in order to determine the convergence of the algorithm. In this matter, the obtained values are presented in the next figure.

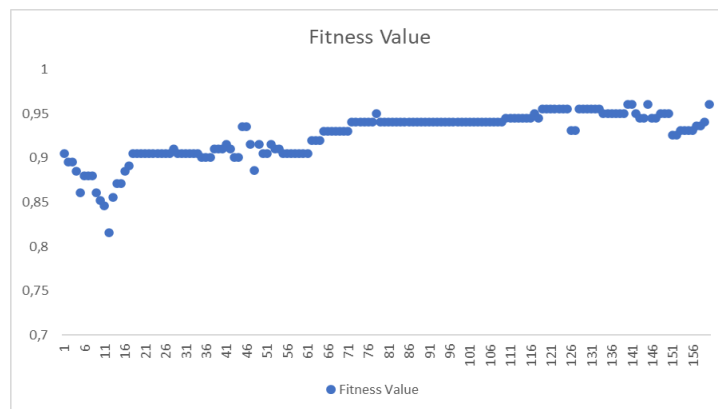


Figure 6. The convergence of the genetic algorithm

We can observe that the value of the fitness grows with each generation, with a minimum of 0.81 and a maximum of 0.96, reached at the final generation, meaning that the algorithm approaches a global optimum. The convergence rate for the fitness values is approximately 0.004. This indicates that the changes between consecutive fitness values are quite small, suggesting that the algorithm is approaching a point of stability and converging towards an optimal solution.

In order to determine robustness, we have calculated the statistical indicators after a set number (100) of genetic algorithm runs. For each run, the best chromosome obtained after the final generation was selected. The statistical values obtained for the 100 runs of the genetic algorithm provide an overview of its performance. The average fitness of 0.9395 indicates that the algorithm tends to reach consistently good quality solutions, with an overall performance that is close to optimal. The standard deviation of 0.0198 suggests a relatively small variation between the fitness obtained in each run, which indicates a stable and efficient convergence of the algorithm. It does not produce large fluctuations in performance, which may be a sign that the algorithm stabilizes quickly towards an optimal solution. The minimum fitness of 0.8609 and the maximum fitness of 0.9650 show that there is some variation, but that the solutions obtained are generally very close to the maximum possible value. In conclusion, these indicators suggest that the genetic algorithm used is efficient and convergent, with consistent performances and close to ideal solutions.

In order to determine the behaviour of the algorithm for specific values of the parameters, we have established specific values of these parameters, while a selected one was changed progressively. For the general setup, the values of the parameters were established to be $NP = 50$, $NG = 50$, $m = 10$, $rc = rm = 0.5$, $TG = 30$, $w1 = w2 = 0.5$ and $S = 10$. The fitness values obtained for progressive (with a growth rate g) values of selected parameters were obtained. The selected parameters were NP (with $g = 10$, 50 runs), NG (with $g = 10$, 100 runs), m (with $g = 1$, 100 runs) and $w1$ (with $g = 0.01$, 100 runs). The values obtained for the given setup are shown in the next figures.

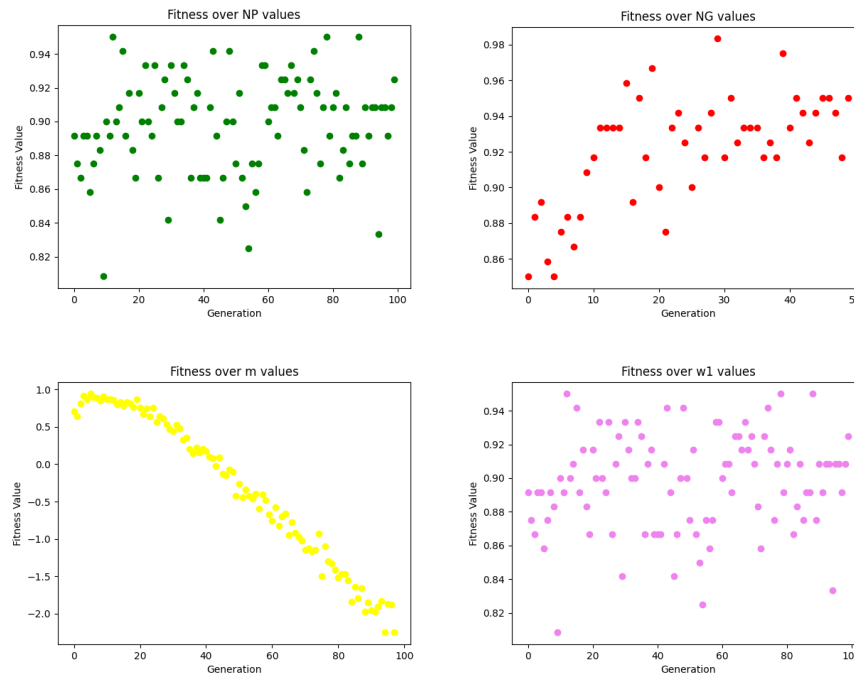


Figure 7. Values of fitness function for different values of NP, NG, m and w_1

The dependance of the algorithm has a strong connection with the parameters. The correlations are established as follows:

- The correlation coefficient of 0.1265 suggests a very weak positive correlation between NP and f. That is, there is a positive relationship between these two variables, but it is very weak and probably not statistically significant;
- NG and f have a positive correlation of 0.6297. This means that as NG increases, f tends to increase as well, but the relationship is moderate. A correlation of 1 would indicate a perfect linear relationship, so this suggests a moderate association between the two variables;
- m represents the number of questions in a test, and f represents the fitness value. A correlation coefficient of -0.8889 suggests a strong inverse relationship between the two variables. That is, as m (the number of questions) increases, f (the fitness value) decreases in a fairly consistent manner. The decrease may be also determined as the time (TG) was set to the double of questions, while the number of items increases;
- The correlation coefficient of -0.1819 indicates a weak negative correlation between w_1 and f. That is, there is a negative relationship between these two variables, but this relationship is quite weak and

probably not statistically significant. This may mean that this suggests that, in general, response permutations that receive a higher weight do not lead to better genetic algorithm performance.

As for the Eval and Verif components, the implementation captures the mechanism of test solving and assessment performance. Screenshots of implementations related to these two components are shown in the next figure.



Figure 8. Implementation of Eval and Verif

The model's effectiveness is constrained by the lack of empirical validation for fitness function parameters, limiting adaptability across educational contexts. It also relies on predefined question structures, restricting flexibility for open-ended assessments. Additionally, scalability challenges may arise in large-scale applications, and comparisons with existing AI-based test generation tools are needed.

In conclusion, the model appears to be very consistent and performant, especially related to Items component and is achieving good results with little variation between runs. The average fitness of 0.9395 is very good, and the small standard deviation suggests that the algorithm is robust and does not generate very poor solutions. However, there is room for possible improvements, such as optimization to achieve higher fitness values in each run.

4. Conclusions and future work

Future research should refine the fitness function, integrate the model into e-learning platforms and enhance scalability in large-scale educational assessments. Comparative studies with machine learning-based approaches would further assess its effectiveness in adaptive testing environments. One key direction is refining the fitness function by incorporating dynamic weighting mechanisms based on learner profiles and real-time performance data. Lastly, the three components of the presented model can be integrated into a web or mobile platform to obtain a complex application with many e-learning features, such as those in (Popescu et al., 2023), (Hamidi et al., 2011) and (Popescu et al., 2021a).

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Research on the harmful impact of digital technology on effective learning in adults

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Abstract: *The advanced digital technologies use in the adult education system represents a real advantage through the facilities offered for the educational process, for the production and development of knowledge. These are also accompanied by a series of risks regarding the quality of content and correct learning. In our paper, we present the comprehensive results of our research and propose a strategy and a platform for educational support of human resources institution, against the background of the development of analytical skills and critical thinking.*

Keywords: Learning styles, Digital Technologies, Digital Educational strategy, Online educational platform.

1. Introduction

In the digital age, technology has revolutionized the way for learn, interact and access information. The Internet, disruptive educational technologies (AI/ML), mobile electronic devices (phones, tablets, laptops etc.), online platforms etc., have revolutionized the content and the methods of learning, and making the entire educational process much more fluid and volatile.

Both teachers, instructors and educational tutors, as well as learners, have been faced with new types of challenges for learning correctly, in an ethical and accessible way. In this paper, we will refer to the negative effects of the excessive use of digital technologies on correct learning, at the adult level.

2. Features of adult cognitive development

Digital technologies provide essential support to adults for the production, transfer and consumption of information in order to develop knowledge and understand everyday situations. The purpose of this chapter is to briefly present our results on the development of learning skills with the support of digital technology. For this, we consulted and analyzed over 150 papers, articles and scientific communications, books and opinions expressed in interviews and conferences.

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Analyzing the dominant trends, we establish that adult learning styles are: (Amponsah, 2020)

Convergent or pragmatist style – practical learning is preferred over theoretical learning. Learners prefer to reject information that does not have an obvious application, learning being achieved through autonomous and responsible thinking;

Divergent style or reflective observation – is the style characteristic of adults who have the ability to deepen into problems, ensuring sufficient time for investigations. For them, learning is understood as a process of using previous knowledge (own and identified in various sources) to give meaning to the acquired experience, correct cognitive processes and improve future actions. Cautious resolution of new situations, with the risk of forming wrong perceptions to third parties regarding their slow thinking or the existence of weaknesses in the cognitive process, is the basic dominant.

Theoretical style – is specific to those who approach situations in a logical, step-by-step, vertical manner, with the aim of assimilating disparate events into coherent theories. They synthesize information through systematic and analytical approaches through complex algorithms, having a low tolerance for uncertainty, disorder and ambiguity.

Other studies classify learning styles differently, depending on the criteria chosen. Given this diversity, we believe that the effort to create a unique educational product or program is unreliable and expensive. An educational product that is useful to most may distract others.

Based on contemporary digital technologies, which offer a wide range of educational platforms, adults can choose a method according to their learning style. In this context, divergent trajectories and diversity could negatively affect the learning of senior adults, who either do not have technology skills or are stimulated by methods determined by their profession or hobby (Neagu & all, 2024). Recent studies have demonstrated that the potential for improving learning and developing intelligence through cognitive training, mainly through gamification, improves academic performance or learning in the workplace (Badawi & Ciupercă, 2023).

Particularly at this historical stage, the rapid implementation of digital technologies can be approached as an element of novelty in work, as an opportunity to learn new things and be exposed to new information, as a routinization reduction etc., all of these elements supporting intellectual growth (Staudinger et al., 2020).

The main advantages are:

Accessibility to expanded educational resources – online educational materials can be accessed from any location, 24/7, allowing adults to learn at their own rate and in accordance with professional and personal schedule availability opportunities, without the need to take a formal course;

Personalized learning – technology can be adapted to the needs and motivational requirements of the learner, with online platforms providing real-time feedback, progress testing, recommendations for additional study materials and additional training sessions;

Improving collaboration and interaction – digital educational technologies create opportunities for learning and exchanging ideas with virtual colleagues;

Stimulating motivation through gamification – in the learning process, gamification can stimulate motivation by integrating certain rewards, rankings, competitions etc., into the game. In addition, some adults can train and develop their digital skills, an essential condition for the professions of the future.

3. Disadvantages of excessive use of digital technologies in adult learning

The lack of basic digital skills, in addition to limiting access to knowledge, can undermine the motivation to learn and preserve self-satisfaction. This disadvantage will lead to isolation, similar to replacing direct human interaction with a pseudo-online life through the excessive use of digital technologies.

Other disadvantages are related to the superficiality of information in the online environment, the distraction of attention in its proximity, the development of cognitive errors and the loss of critical thinking skills.

3.1 Unlimited access to information and the risks of superficiality

Easy access to enormous amounts of information can have negative effects on the learning process of adults by quickly obtaining answers to questions based on scientifically uncertified content. Adults who rely on online search engines to obtain information may only learn basic concepts and may be “fooled” by a multitude of controlled or fragmentarily documented information (for example, false information generated by AI technology, through deep-fake techniques and other methods of social engineering etc.).

In addition, unlimited access to information can lead to a lack of discernment in selecting answers from relevant sources. It is known that many online sources are not verified for accuracy, the main criterion for selecting information being only the large number of followers. Thus, the content disseminated on social media platforms can contribute to the formation of misconceptions or incomplete concepts, generating various conspiracy theories, without a scientific basis but easy to understand. Let's give the example of the “Flat Earth Theory” (Baugh, 2024).

3.2 Distraction and the impact on concentration during learning

Frequent use of digital technologies, especially mobile ones, can contribute to loss of concentration and distraction. Online notifications, information routines

on social networks, digital messages via email or social media platforms etc., can significantly contribute to distraction and fragmentation of attention during the learning process, resulting in loss of concentration and increasing the time allocated to this process.

In addition, excessive use of the internet and digital technologies can cause procrastination, unnecessary waste of time, neglect of activities and other aspects related to professional or social duties. Studies show that multitasking or attempting to carry out several activities simultaneously, especially in the online environment (for example, reading an article while responding to WhatsApp messages), can negatively affect the understanding and retention of information, which leads to superficial learning.

3.3 Cognitive errors and lack of critical reflection

Exploiting online content without an appropriate educational method can produce cognitive errors. For example, adults who overuse information produced by AI/ML chatbots may end up accepting the information automatically, without passing it through specific filters for critical analysis (Stănescu, 202).

Besides, algorithms that analyze and provide information based on past behavior can create “information bubbles” in which adults are exposed to only certain types of content. This limits the diversity of information sources and the perspectives of critical analysis, creating a narrowing of the information front between milestones that allows the perpetuation of misconceptions or incomplete learning. And dependence on online information resources can stimulate or redirect user behavior.

3.4 Eroding adult autonomous and critical learning skills

As digital technologies are increasingly implemented in everyday life, there is a risk that more and more adults will become dependent on digital platforms and services. This increases the risk of reducing autonomous learning from books, other bibliographic sources, direct interpersonal interaction, etc. Technology, by its nature, can replace these traditional forms of learning, but it can also hinder the process of developing critical thinking skills and in-depth analysis of a subject. Excessive exposure of adults to an online learning system will lead them to consume information without fitting it into a coherent conventional framework, with application in everyday life, to stimulating mechanical learning or fragmentation of ways to solve a situation.

3.5 Negative effects on mental and physical health

Over time, excessive use of digital technologies can have negative effects on students' mental and physical health. There are medical studies that show that prolonged exposure to screens can cause eye strain, insomnia and stress, which in turn can affect the ability to concentrate and retain information. (Devi & Singh, 2023).

Also, excessive use of digital technologies can lead to a decrease in direct human interaction and social isolation (Grey & all, 2024). Adults who spend a long time in front of a screen may, over time, lose the ability to communicate directly with peers and instructors, eroding the possibility of learning or exchanging ideas in collaborative groups or teams.

4. Discussions and observations

An educational ecosystem, based on digital technologies, for adult learning is the only solution to transform existing theories and scientific research results into elements for improving social well-being and health. It will allow resources to be used harmoniously, through a sharing of strategies and action plans, in various directions whose major objective is to ensure security and personal, professional and social development.

Currently, there are institutional initiatives that have started to model the systemic relationships of education in an ecosystem, such as the STEM platform (science, technology, engineering, arts and mathematics). It approaches learning as an access point for the development of dialogue and critical thinking (European Commission, 2023), for the preparation of a quality workforce and for the literacy of citizens for a highly technology-based society. Other solutions use gamification as innovative educational tools for teaching STEM/STEAM courses such as: BBC micro: bit, VR Learn, pi-topOS, Soundtrap, Augie (developed by Pai Technology), CollabSpace etc. (EdCan, 2019).

Based on lessons learned and dialogue between experts in educational sciences, a national strategy can be established, which will establish the framework for coordinating development efforts, in the long term, regardless of the political color of the government and the functioning of institutional relations between the private sector and civil society.

Among other things, this strategy will be able to ensure:

1. Improving governance through coherent mechanisms to ensure monitoring and evaluation of education progress and adaptation of the workforce to new market requirements;
2. Strengthening national security through internal and external measures to prevent misinformation and manage crises, knowing that disinformation and misinformation represent the greatest risk estimated for 2025 (World Economic Forum, 2025);
3. Social integration and cohesion through measures to reduce inequalities, combat discrimination and integrate vulnerable groups;
4. Technological development and innovation by stimulating investments in education, to train the workforce in technological fields, in digitalization, in emerging technologies etc., which can transform the structure of the economy and the entire society.

Another aspect in which it favors the wrong education of adults concerns the dynamics of changing online sources that provide mentoring, depending on reward policies and not on the quality of information. This trend, combined with a strategy based on the “sense of belonging” of the learners, determines that the graduates' certificates represent only a recognition of the formal history of training and not an acquired skills. We believe that the policies of some institutions regarding employment practices should also emphasize online platforms for testing a candidate's practical skills. Such a solution will be a useful tool for identifying the best position and role that a candidate can hold in the organization. In addition, it can stimulate confidence in one's own capabilities, contributing essentially to the formation of a lifelong learning culture, through which citizens can remain anchored to the challenges of societal evolution.

5. Conclusions

Freedom of expression is a fundamental right essential in a democratic society. This right includes, in addition to freedom of opinion, the freedom to receive and dissemination of information. Current digital technologies are a useful tool for exercising this right, with the advantages and risks that arise from unlimited access to information.

It is essential that learning is exercised responsibly, in a framework that promotes critical thinking and deep learning. It is important to emphasize the development of autonomous learning skills and the encouragement of personal reflection in order to prevent the negative effects of the use of digital technologies, in a complex information environment, with a multitude of dangers associated with the digital world.

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Section 4

Instructional Design in Digital Era

The Clip Thinking Phenomenon: The typology of technological products for the bounds' overstepping and strengths' leveraging in the educational needs

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Abstract: *The paper represents a theoretical and conceptual scientific study by reference to the phenomenon of Clip Thinking, analyzed through the notional prism towards its limits for which it was stigmatized. By listing the existing research that explores tangential topics of the approached theme, the author tries to highlight the strengths of the research object, the CT phenomenon (CTP), capitalizing on them by using cutting-edge technological products.*

The current research addresses the solution of the CTP problem through the descriptive recommendation of a series of technological tools included in a systematic, authorial distribution, presented under the generic "classification of technological products to overcome the limits and capitalize on the strengths of CTP".

The given material is addressed to the teaching staff interested in capitalizing on cutting-edge digital tools in their professional activity carried out either in the pre-university or in the university environment in a constructive way that would reduce or eliminate the negative effects on the psychological and/or cognitive structure of the learner.

Among the methods used by the authors are the analysis and synthesis of specialized literature from such fields as educational sciences, learning psychology, general didactics, information and communications technology, and software product development.

Keywords: Clip Thinking, university didactics, cutting-edge technological products, engineers in the fields of computer science.

1. Introduction

The prominent characteristic of the digital age, **the 24/7 accessibility of ICT technologies and products, and more recently AI**, has partly generated the temptation, but also the dependence of users to access them permanently for various reasons (Burlacu, 2023; Ibrahimov, 2024; Manal, 2024). The intention of the educational system, as well as of their representatives, to meet the expectations of the learner transforms the methods, procedures, and teaching strategies to adapt them to the process, but also to the teaching act itself, as much as possible to the

needs, sometimes the requirements, and desires of the learner (Burlacu, 2015; Burlacu, 2016a). One of the results of these efforts is the launch and promotion of international (Gabriel et al., 2022), national (Burlacu, 2019b), and local (Burlacu, 2019a) policies for the valorization of digital technologies and software products in the teaching-learning-assessment-self-assessment process at various levels of study (Burlacu, 2016b; Burlacu, 2021b; Burlacu, 2021c).

The abundance of information and its almost continuous access often desensitize the perception of users, which is the cause of the emergence and formation and/or development of a new type of data processing by information consumers, often coming from digital sources. The phenomenon in question, known as clip thinking, can be characterized as a way of processing information in a fragmented, most often superficial, manner.

Leaving aside, for now, the reasons for the emergence and spread of such a cognitive habit, we must note that, although in the opinion of some researchers, this ability has certain deficiencies (Bkhat, 2018), once these are known, they could be taken into consideration to be exploited from a didactic point of view.

The idea of CTP valuing, from didactic considerations, constitutes **the problem of this theoretical research**. Given the natural context of the digital age in which we live, theoretical reflections on potential solutions to the formulated problem will contain aspects of the fruition of technologists and software products in terms of improving/diversifying teaching-learning-assessment-self-assessment practices in interaction with students characterized by the presence of CTP, that is, by the existence, with some degree of preference, of consuming information in a fragmented style.

The objectives of our research were formulated as follows: (1.) a brief theoretical introduction to the notion of CTP; (2.) an analysis of the pedagogical and psychological aspects of CTP, as well as (3.) the creation and presentation of the typology of didactic and technological tools to be applied in education with the aim of improving the less desirable effects of CTP; (4.) a conceptual description of the items included in the typology of given tools, as well as an analysis of their functionalities and purpose. The article is addressed to those interested in the phenomenon of CT, mostly actors of the teaching process, teachers—students and/or educators — learners and/or parents, but also to scientific researchers in the fields of pedagogy, psychology, and software product development.

2. General presentation of the Clip Thinking Concept

The phenomenon of clip thinking is a notion with some history. This phenomenon begins to be reported with the observation by scientists of cognitive changes, apparently determined by the progress of mass media, among consumers of mass media products. Given that these transformations were recorded around the middle of the 20th century, predominantly, consumers of mass media products

inclined towards the formation of CT were viewers, that is, representatives of the population who preferred watching television programs. As early as 1964, from the writings of Marshall McLuhan, the idea of the theoretical and applicative potential held by products developed with the support of various media, which today we would call multi- and/or macro-media, in transforming our way of thinking and perceiving the world is clearly evident. Currently, there are studies that reflect the concerns of their authors on various aspects of the phenomenon of CT, among which we also attest attempts to define the concept in question.

For example, according to Bkhat (2018), “clip thinking” is seen as “a process of reflecting a multitude of different objects, disregarding the connections between them, characterized by the complete heterogeneity of incoming information, the high speed of shifting between fragments of the information flow, and the lack of the integrity of the perception of the surrounding world”. While Volkodav et al. (2017), who analyze the CT phenomenon from an interdisciplinary perspective, consider that “The phenomenon of clip thinking is essentially synonymous with the concept of 'cognitive style’”.

Among **the scientific dimensions related to the CT phenomenon** are:

— *Adapting GT culture for education.*

The ways of adapting (Bkhat, 2018) the “clip culture” to educational technologies are studied by structuring information in the form of clips, changing the presentation format, and using vivid, clear, and visual presentations, which will improve the learning process for young people who have already formed the clip thinking.

— *Examining the relationship between CT versus the phenomena and/or psychic processes of the individual involved in an interaction with digital products.*

The research after Dautov, Korochentseva & Hussini (2019) proposes to solve the problems related to the analysis of basic approaches tangential to the study of clip thinking, examining the relationship between the phenomenon of clip thinking and attention.

The respective work is empirical and offers: assessing the level of clip thinking among representatives of generations X and Z; a description of the investigation process of attention mechanisms among representatives of generations X and Z; establishing the existence of connections between clip thinking characteristics and attention characteristics in representatives of the sample of generations X and Z; and detection of significant differences between the characteristics of clip thinking among representatives of digital generations and up-network generations.

Clip thinking “[...] is a result of our limited attention spans and the fast-paced nature of the digital world we live in. Instead of engaging in deep, focused thinking and analysis, we often find ourselves skimming through headlines, scrolling rapidly through social media feeds, and consuming information in bite-

sized portions (Toffler, 1970; Carr, 2008). The view on CT, which emerges from another set of research, is that it may be the result of "our attention span", but also of the natural speed, specific to today's digital world. Thus, according to Toffler (1970), and also Carr (2008), instead of engaging in "[...] deep and focused thinking and analysis [...] often", people waste their time scrolling almost unconsciously through posts on social networks, thus consuming "information in bite-sized portions".

While Bushuyev et al. (2024) capitalize on "clip thinking is a prevalent thinking pattern in the digital era, shaped by the fast-paced nature of technology and information overload".

3. CTP from psychological and pedagogical perspectives

Flashing thinking disrupts the balance of mental cognitive processes, enhancing or weakening the specific properties of a certain cognitive sphere (Dautov, Korochentseva & Hussini, 2019). This causes a decrease in the quality of selected information (Girenok, 2016), as well as the penetration and impact of third-party factors into the perimeter of the main phenomenon under investigation. Additionally, this fact burdens and disorients a person's work, as a whole.

According to Bushuyev et al. (2024), the emergence of such cognitive behavior is the result of either "[...] our attention span and the fast-paced nature of the digital world we live in", or being absorbed by obligations, as well as the stress of dealing with them in situations of minimal relaxation: "we often find ourselves browsing the headlines, scrolling quickly through social networks, and consuming information in small portions (Toffler, 1970; Carr, 2008).

In our opinion, cognitive transformations specific to CTP have both positive and negative implications. We assume that among the positive aspects of the presence of CTP would be the fact that it allows the rapid selection and synthesis of an extensive range of information by the CTP carrier. Being "affected" by CTP, the person can (1.) stay up to date with current events while (2.) performing multiple tasks in an efficient manner. We also believe that CTP would serve as an enhancer to stimulate human creativity and promptness in terms of generating and exposing ideas and their implementation perspectives.

Previous studies were conducted on the effects of human-computer interaction, but also on user-learner and digital devices/software products developed through cutting-edge technologies, serving as direct arguments for possible results of the formation and/or development of the Clip Thinking phenomenon at the individual level.

The investment documentation approach allows us to state that the consumption of information generated and/or disseminated through high-tech products comes with certain consequences for the user, in the case of our field of interest, this being, inclusive, the one who learns. Thus, the conducted research

shows that the set of cognitive, psychological, and behavioral characteristics of the consumer of digital products is affected. Among the possible dimensions with a negative effect of CTP on the consumer of digital products and/or information, there are scientific works that highlight (see Figure 1):



Figure 1. The influence of CTP on the consumer of digital products/information

— *Critical thinking and learning skills*

The possibilities of continuous access to the products of the digital world can lead to a decrease in the ability to concentrate, as well as the ability to think deeply (Carr, 2020). Analyzing scholarly opinions according to which CT leads to the diminution, or even the loss, of the ability to analyze perceived information under a critical prism, we found that this CT, affects self-motivation, learning ability, decision-making, and, in the long term, the quality of life.

According to Kraynov & Shalaeva (2020), the consumer of digital information is “deprived of the ability to critical reflection”, thus causing the “formation of a mosaic-type consciousness” that leads to the absorption of these materials for “pleasure”; this “psychological processing” is carried out in an involuntary manner. Additionally, excessive use of digital media is associated with poorer cognitive control, including attention and inhibitory control (Carr, 2020).

— *Decision-Making Mechanism*

Digital distractions are another aspect of technology that can affect decision-making. Continuous digital distractions may reduce the cognitive capacity for

careful deliberation, leading to more impulsive decisions (Duke & Montag, 2017). Participants who were interrupted by a text message while performing a decision-making task showed a decrease in the quality of their decisions, highlighting the impact of digital distractions on decision-making ability (Mark et al., 2017).

— *Attention*

The user of digital products and information ends up forming the so-called “continuous partial attention”. The phenomenon is characterized as a symptom of the user’s attention overload (Firat, 2013), which is a specific characteristic of the digital age. Speaking of “continuous partial attention”, we must mention that the term refers to the continuous need of the user of digital products and information to divide/permute/retain attention on several tasks or stimuli. Because the action takes place continuously and simultaneously, the user-learner fails or sometimes may not even intend to delve into the essence of what is taught-learned-assessed in the didactic process, which, as a result, affects the acquisition of new knowledge, skills, and, ultimately, special/professional skills of quality.

— *Memory*

For some time now, the scientific community has begun to use the notion of digital dementia. This notion reflects the formation of a cognitive regression caused by the excessive use of digital technology (Preiss, 2014). The phenomenon is gaining momentum among proactive consumers of digital products and information. There is research (Manwell et al., 2022) that claims that digital dementia causes functional-cognitive deficits, including the weakening of memory capacity; the appearance of hyperactivity disorders characterized by loss of attention, and a reduction in communication skills, but also the ability to make decisions. Obviously, among the consumers exposed to a higher risk of developing these deficiencies are representatives of the younger generations and/or dedicated users of cutting-edge technological products.

— *Addiction*

Addiction to the consumption of digital products and information can also accompany the impairment of the decision-making mechanism. Neuroscience research has informed those concerned with the implementation of technologies, including for educational reasons, that excessive consumption of content from digital media generates low levels of self-control, which affects the decision-making process of users of such products. The results of the study state that such users often make decisions based on impulse, and for those of them who are engaged in a study process, that is, they also have the status of a student, this aspect leads to a decrease in academic performance (Wilmer et al., 2017; Shanmugasundaram & Tamilarasu, 2023).

— *Curiosity and the perception of the new*

Unequivocally, curiosity and the perception of the new are natural and determining components of human cognition. Today, when digital technology

products offer an infinite number of new topics and approaches to people interested in expanding the horizons of individual and global knowledge, it would be a great sin not to resort to their inclusion in education. To satisfy the exploratory curiosity of the learner and / or any other individual oriented towards knowledge, but also for teachers tempted to adapt to the technological trends of the digital age, there are a multitude of strategies, environments, and technologies that respond to the needs and / or desires for training and development of the skills to be acquired within the teaching process. Here it is appropriate to mention the expansion of didactic formats, both classroom and non-classroom and/or online (Burlacu, 2021b) and offline (Burlacu, 2021a); and the transition from purely theoretical formats to applied ones.

4. CTP: Technological Tools to Be Applied in Education

Although the results of scientific research in the field of behavioral and/or cognitive sciences could already serve as evidence of possible effects of the interaction of the user of digital products-student at the level of CT training, this being a contradictory phenomenon, it has managed to arouse the interest of scholars concerned with the educational integration of digital and finite products generated by cutting-edge technologies.

Clip thinking (Dautov, Korochentseva & Hussini, 2019) upsets the balance of cognitive mental processes, enhancing or weakening specific properties of a particular sphere. This leads to a decrease in the quality of the selected information, as well as the mixing of third-party factors with the main investigated phenomenon, which additionally loads and disorients the work of a person as a whole (Kushnir & Khachatryan, 2022).

In our opinion, under the generic term "work" can be included various types of intellectual and physical activities, as well as the activities tangential to the teaching process. In this sense, for the actors involved in the teaching process, the pupil-learner-student, on the one hand, and the teacher, on the other, it becomes imperative to strengthen the mental faculties of the learner, capitalizing on digital tools for educational purposes.

Primordial in selecting the technological tools necessary for capitalizing on the learner's CTP skills is their selection based on (Burlacu, 2014; Burlacu, 2020) didactic and educational considerations, as well as those related to the psychology of learning.

However, based on the factors listed, in our view, for interested teachers, but also for developers of educational software products, a clarification would be necessary on the typology of digital and technological tools capable of responding to the solution, if not total, at least partial, to this problem. For these reasons, the classification diagram was created (see Figure 2), followed by the description of each component of this typology.

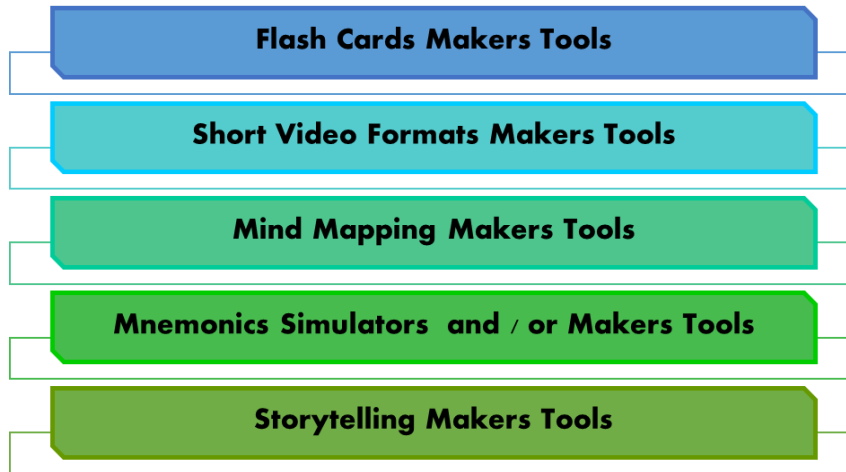


Figure 2. Typology of applications to overcome CTP limitations

If we are to analyze the functionality, but also the area of applicability of the proposed typology of tools, we must mention that the postfix of Makers Tools, common to all the elements listed in Figure 2, represents the fact that for these categories of teaching materials there are various digital tools, online or desktop applications, platforms, or components thereof that offer the possibility of creating such educational materials.

Based on these, we will list below a brief description of these teaching tools.

Flashcards: teaching materials that can exist in physical or electronic format, containing information, usually textual and/or graphic. In electronic versions, there is the possibility of using animated effects, soundtracks, and video sequences on one of the two sides of the flashcard. From a didactic point of view, flashcards are predominantly used for memorizing, updating, reproducing, and recalling theoretical concepts, but also certain practical contexts of their use.

Short Video Formats are videos, the entire content of which is very, very short. If we start from the specialized platforms for which they will be broadcast, their duration must be from 5 to 90 seconds. At the moment we are talking about platforms that recognize, accept, and store in the long term, but also broadcast such content. Such host platforms are Instagram, TikTok, and YouTube. As a rule, these platforms are flooded with commercial content, oriented towards potential customers and consumers of certain products, classic in this sense being videos that fall into the genre of videos created for the digital marketing area. Clearly, representatives from the education field, often in the person of various providers of various courses, trainings, and afterschool programs, but also larger educational entities, have taken over this trend. Currently, there are also teachers who try, if not to film themselves, at least to use or challenge their students to film such video sequences, capitalizing on them within the teaching process and / or in their eventual projects.

Mind Mapping was conceived as a brainstorming technique, which is used to organize data/information/concepts so as to facilitate the visual perception of the total and/or partial connections existing between them. As a rule, the arrangement of information through applications and/or only functionalities included in certain software products (accessible online or in desktop application versions) capable of creating mind mapping is carried out in a hierarchical form; key ideas are present as the central point of the diagram of the given type, and secondary topics that branch out are connected to the notions/ideas that support and/or explain them.

The respective technique, but also the mind mapping diagrams themselves, allows the overall analysis of the way in which ideas/phenomena/concepts, etc., appear, evolve, and also interconnect with each other. Thus, this tool offers the possibility of fixing the questions/problems formulated, generating possible new solutions sometimes based on the detection of new cause-effect dependencies.

Mnemonics Simulators: Its etymological analysis denotes a Greek origin later taken over by the French (> [< fr. mnémonique, cf. gr. mneme – memory]. From here, the analysis of the semantics of the term makes us conclude that it means "facilitating/helping memory". Mnemonics Simulators, also called mnemonic devices, allow the individual to organize and/or extract memorized knowledge more efficiently, operating according to the principle of anchors through which the human brain assimilates/stores/extracts information. Mnemonics Simulators can be in the form of images, video sequences, acronyms, rhymes, and slogans — fragments presented in any format — as a basic characteristic endowed with the ability to generate certain associations.

Storytelling turns out to be, in fact, a story exposed/broadcast in oral or digital format. Being a form of communication, which capitalizes on words and/or actions, it involves a storyteller and a listener/a group of listeners. Because storytelling involves at least two roles, that of storyteller-speaker and that of listener-receiver, this technique can also be considered an interactive artistic teaching method.

5. Conclusions

Our research tends to highlight the problem of the CT phenomenon, tangential to an educational process specific to the digital age and, namely, that of massive integration of technology in education, but also in the direct teaching act. In this context, this paper also proposes solutions to reduce the harmful effects of CTP training and development; here, as saving tools, various teaching materials deliverable in digital formats are capitalized on.

The respective teaching tools are: (1.) included and described in the author typology presented in this paper; (2.) recommended for use within the teaching-learning-evaluation process and; (2A.) either already exist and should be taken into account by teachers at various levels of study, but also curricular areas of school or

academic education; (2B.) or could be kept in view by those software developers who are interested in creating and implementing potentially useful applications in the field of education, as well as those addressed to the general public, respectively, oriented to respond to a wide spectrum of imperatives of the socio-economic environment, in order to reduce the risks of the occurrence of CTP in future users.

Although, in our view, the analyzed tools are promising from the point of view of the benefits brought to those involved in the educational act, their analysis at the level of impact on increasing the degree of student involvement, flexibility of the teaching-learning-evaluation process; efficiency of a technology-assisted teaching process; adaptability and personalization of the pace and/or degree of complexity of the teaching content; and monitoring of the progress of students could be subjects of possible scientific studies.

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Social and economic predictors of digital skills. Benchmarks for public policies in a time of 4.0 Revolution

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Abstract: *Since the launch of the Digital Agenda for Europe (2010), the European member countries have developed policies, strategies and programs to stimulate the digital economy in the context of advancing information and communication technology. Increasing digital skills and inclusion has become essential for governments, businesses, academia and the non-governmental sector. Apart from the technical conditions (internet access, critical infrastructures and digital devices) necessary for the development of digital skills, education and training in the field of information and communication technology must be improved by offering training and specialization courses at the same time as personal motivation and stimulating interest in the prospects of a life of quality in an increasingly digitized society. This research aims to evaluate the impact of social and economic predictors (independent variables) on the level of digital skills (dependent variable), with the potential to identify areas for improvement and strategies for growth. The research methodology includes the statistical analysis of the variables (risk of poverty and social exclusion, participation in education, PISA results at math, early leavers from education, GDP per capita, government spending on education), correlation and multiple linear regression, principal component analysis (PCA). The study will also use cartographic processing for comparative analysis at the EU-27 level. The general assumption is that government initiatives, investments in digital infrastructures and educational programs that promote digital literacy play a key role in the policy-making process in an era of digitalization in which the advance of so-called Revolution 4.0 marks the society and the economy.*

Keywords: digitalization, digital skills, digital literacy, socio-economic predictors, public policy.

1. Introduction

The world is currently experiencing the Fourth Industrial Revolution (Revolution 4.0) characterized by digitalization (WEF, 2016). We are witnessing a significant spread of information and communication technology (ICT) across all sectors. This phenomenon is evident in automation, robotization, and

computerization, which transform analog information into digital formats. These advancements aim to enhance efficiency, drive innovation, reduce costs, and maximize outcomes.

Nowadays, education and training become irrelevant without computer devices and digital technologies, but also without people who do not have the digital skills to use them. The labour market is being reshaped by automation, robotization and informatization. Employees who focus on developing their digital skills will undoubtedly emerge as the winners of the 4.0 Revolution. In contrast, those who remain digitally illiterate may face marginalization and social exclusion. Therefore, it is essential for governments to collaborate with businesses and non-governmental organizations to identify socio-professional groups at risk of social exclusion due to their lack of digital skills.

Since the 2000s, discussions about digital competencies at the European level have emphasized the importance of digital literacy for maintaining the economic competitiveness of European Union member states. This focus aims to enhance the skilled workforce. The 2006 Recommendation of the European Parliament and the European Council on key competencies for lifelong learning was one of the first documents to highlight the development of digital competencies needed for communication, work, and leisure in our increasingly technological and computerized society (European Council, 2006).

In 2010, the European Commission initiated the Digital Agenda for Europe, which is a pivotal component of the broader Europe 2020 Strategy aimed at fostering innovative, sustainable, and inclusive growth across the continent. The Digital Agenda for Europe emphasizes the transformative role of ICT in addressing critical societal challenges, including climate change mitigation, demographic shifts associated with an ageing population, and the promotion of active ageing strategies.

The European Commission launched the first version of the European Digital Competence Framework (DigComp 1.0) in 2013. This framework is structured around five key competence categories: information and data literacy, communication and collaboration, digital content creation, security, and problem-solving (European Commission, 2013). In 2014, the European Commission began assessing the digitalization progress of EU Member States through the Digital Economy and Society Index (DESI). In 2017, the Digital Education Action Plan (2018-2020) was introduced, promoting the integration of digital competencies in education and vocational training.

In 2022, DigComp 2.2 was published, which also includes aspects related to the use of artificial intelligence in the context of cybersecurity to ensure the well-being of beneficiaries. In European documents, digital competencies are “the confident, critical and responsible use of digital technology for work, learning and participation in society” (European Commission, 2013, 2016, 2022).

The United Nations Educational, Scientific and Cultural Organization (UNESCO) defines digital competencies as "the skills needed to use digital, communication, and network technologies safely and effectively for purposes such as information sharing, communication, and problem-solving" (UNESCO, 2018). This definition highlights the importance of digital interconnectivity under secure conditions to accomplish various tasks.

The Organization for Economic Co-operation and Development (OECD) defines digital competencies as a combination of technical knowledge, critical thinking, and cognitive skills necessary for effective work and learning in a digital environment (OECD, 2019).

2. Literature review

This study section will present a series of approaches to digitalization and the formation of digital skills in a society of knowledge and innovation. We start from the idea that what seemed like science fiction yesterday is science fact today (Leonhard, 2017). The world is transforming at an astonishing speed under the impact of digital technologies. All technological processes are accelerated to the maximum level. Governments and companies allocate enormous resources for digitalization, especially for the development of artificial intelligence.

Robotization, automation, and artificial intelligence are freeing humans from routine, time-consuming, and energy-draining tasks and processes. As a result, people can now focus on more interesting, complex, and innovative endeavors. Almost all of the devices we use – ranging from household appliances and transportation to communication tools and medical or sports equipment – are interconnected through sensors, networks, digital platforms, and algorithms that provide optimal solutions. To avoid being left behind in the 4.0 Revolution era, it is imperative to develop a digital literacy.

The concept of digital literacy was introduced by researcher Yoram Eshet-Alkalai in 2004. It encompasses the knowledge and skills needed to effectively use computers, software, and the Internet, but it goes beyond just technical skills. Eshet-Alkalai emphasizes the importance of cognitive, psycho-emotional, and social skills required for navigating the virtual environment. Digital literacy includes several components, such as photo-visual literacy, information literacy, and socio-emotional literacy (Eshet-Alkalai, 2004).

Recently, there has been increasing discussion about "digital natives", referring to young individuals who are familiar with digital devices from an early age. Ellen Johanna Helsper and Rebecca Eynon highlight a divide between generations based on their level of digital skills. However, being part of a certain generation is just one factor that influences how someone interacts with the Internet and digital technology. Other important factors include the frequency of use ITC, personal experience, gender, and level of education. (Helsper & Eynon, 2010).

The concept of digital competence is dynamic and multidimensional, and it is examined in various ways within specialized literature, including public policy, education, vocational training, and certification. The European Commission also uses synonymous terms such as digital literacy, digital competence, and ICT skills. In support of this assertion, Anusca Ferrari, Yves Punie, and Christine Redecker present three key arguments. The first highlights the benefits of digital skills in the field of education. Students are motivated to use digital technologies in the learning process, which leads to improved performance. The second argument stresses the ubiquity of digital technologies in contemporary society. The third argument emphasizes that, in a knowledge-based society, functioning without digital skills is increasingly difficult (Ferrari, Punie & Redecker, 2012).

Kashan Pirzada and Fouzia Khan argue that in developing economies, digital skills – including computer literacy, communication abilities, internet proficiency, and advanced digital competencies – are likely to provide job seekers with a significant advantage in obtaining employment and retaining well-paying positions (Pirzada & Khan, 2013).

Digital skills refer to the competencies, knowledge, and attitudes needed to effectively integrate digital technologies (both hardware and software) into various areas of human activity, such as education, vocational training, work, leisure, and participation in socio-cultural activities. These skills involve the use of computer equipment and programs and extend beyond them to include abilities related to communication through digital tools, critical thinking, teamwork both in physical and online environments, as well as the creation and dissemination of digital content (Vuorikari et al., 2022).

Possessing digital skills is also crucial for older people to communicate online with their family and friends, in relation to telemedicine service providers, or with public authorities that have developed digital platforms for the services they offer. Training older people in digital skills must be oriented towards their desires, needs and problems, specific to this age group. Digital pedagogy, the level of training of trainers in digital skills, and the formative content are important in obtaining a level of basic digital skills and above in a comfortable environment for older people (Schirmer et al., 2022).

In a study on digital inequality, Christopher Reddick and his colleagues investigate three important dimensions of digital literacy: access to the internet, use of ICT technology, and their outcomes. The researchers conducted a city-wide survey, using both paper and electronic questionnaires, to examine all three dimensions of digital inequality. The empirical findings show that the persistence of digital divides is mainly influenced by factors such as demographics, socioeconomic status, geographic location, and language skills (Reddick et al., 2023).

Focusing on differences in digital skills and their impact on existing inequalities, Fabian Kosse, Tim Leffler and Arna Woemmel propose a two-

dimensional approach, taking into account both technical skills (the absolute dimension) in the use of ICT and the skills related to confidence in their use. In this sense, there is a complementarity between cognitive and non-cognitive skills in accessing jobs requiring digital skills. Public policies that aim exclusively to improve digital competence may be insufficient if they neglect the role of confidence in acquiring and effectively using skills. Social disparities in digital skills can amplify existing social and economic inequalities (Kosse, Leffler & Woemmel, 2024).

In this study, we will use the definition of the concept of "digital skills" as formulated by *DigComp 2.2 The Digital Competence Framework for Citizens*: "Digital competence involves the confident, critical and responsible use of and engagement with digital technologies for learning, at work and for participation in society. It includes information and data literacy, communication and collaboration, media literacy, digital content creation (including programming), safety (including digital wellbeing and cybersecurity skills), intellectual property issues, problem-solving and critical thinking" (European Council Recommendation, 2018; European Commission, 2022, 2023, 2024).

3. Research methodology, indicators, data sources

From the literature mentioned in the previous section, it follows that the concepts of "digitalization", "digital literacy", and "digital skills" are correlative and describe the dynamics of a world marked by the 4.0 Revolution. The scientific and technical imagination of people in previous decades is surpassed by the amplitude of digital technologies of the present and the future. Although digital skills are essential for socio-professional integration, people do not have the basic level everywhere in the world to face the challenges related to education and work.

There are disparities in the level of digital skills between countries and regions of the world, also reflected in official statistics and public policy documents. The level of digital skills is explained by social and economic predictors (determinants): age, gender, residential environment, level of education, income, place or field of work, government investments in digitalization, the contribution of the ICT sector to the economy.

The present study analyses the relationships between digital skills and social, education, and economic factors in the European Union Member States. In order to explore this complex topic, we applied a methodology based on a combination of statistical techniques to provide a comprehensive understanding of the data. This study aims to answer the following research questions:

- What is the relationship between the standard of living and the level of digital skills?
- How do the performances obtained by students in the PISA - mathematics tests impact the level of digital skills?

- To what extent do the participation rate in education, respectively the early school leaving rate, influence the level of digital skills?
- What is the impact of economic prosperity (GDP per capita) on digital skills?
- To what extent does the share of public spending on education influence the performance in terms of digital skills.

The analyses were carried out using the XLSTAT software, which allowed the detailed assessment of relevant data sets and the generation of relevant graphical visualizations to clarify the observed trends.

Two distinct data sets were used; the first set focused on the digital skills of the population:

- Individuals with basic or above basic digital skills;
- Individuals with advanced digital skills;
- Individuals with basic digital skills, not all above basic;
- Individuals with low digital skills;
- Individuals with limited digital skills;
- Individuals with minimal digital skills;
- Individuals without digital skills.

The data from the first set were only analysed descriptively, using boxplots to examine the distributions of variables across the different Member States of the European Union. This set provided a general perspective on the diversity of the data without involving advanced statistical analyses. In contrast, the second set constituted the primary basis of the study, being used in all statistical analyses within this effort. This data set was essential for analysing the relationships between digital skills and economic and social factors. The set includes economic and educational indicators relevant to the European context alongside a central indicator on digital skills: “the percentage of individuals with basic or advanced digital skills”.

The second set of data includes the following indicators:

- AROPE (At Risk of Poverty or Social Exclusion) 2018-2022 measures the percentage of the population at risk of poverty or social exclusion, a determinant of social and economic performance.
- Low achieving 15-year-olds in math (PISA) 2018-2022 represents the percentage of 15-year-olds with low performance in mathematics, an indicator of educational quality and the level of mathematical skills.
- Early leavers from education 2018-2022 indicate the percentage of

young people who abandon education before completing upper secondary education, a signal of school dropout and integration into the labour market.

- Participation rate in education 2022 measures the involvement of young people in educational processes, reflecting access to education and influencing the development of digital skills.
- Real GDP per capita 2018-2022 reflects a state's economic prosperity, directly impacting the resources allocated to education and the development of digital skills.
- Education GDP % 2018-2022. The percentage of GDP allocated to education indicates the priority given to the education sector and the support for developing digital skills.

Regarding the statistical techniques applied, we used four main methods, each chosen to address different aspects of the analysis: boxplot analysis, Pearson correlation, multivariate linear regression, and principal components analysis.

The first graphical tool used in this study was the boxplot, which allowed for exploring the distributions of the two data sets. In the case of digital skills, boxplots were applied to analyze variables reflecting the proportions of individuals in different categories of digital skills, from basic to complete lack of them. This graphical approach helped to identify significant discrepancies between the Member States of the European Union, highlighting not only the median values and quartiles but also outliers that indicate areas of interest for further analysis.

Similarly, boxplots were used for educational and economic indicators to compare their distributions across EU member states. Thus, interstate variations in key indicators such as AROPE or GDP per capita were explored, providing a clear perspective on the structural differences between the countries analyzed.

Pearson correlation was used to investigate linear relationships between variables of interest. This method allowed us to identify how much digital skills correlate with various educational and economic indicators, such as PISA performance or GDP per capita. The results provided a detailed understanding of how economic and educational factors influence the digital skills of the European population, thus constituting a starting point for further analyses. Pearson correlation also represented an alternative view to the results obtained within the framework of multivariate linear regression.

We applied multivariate linear regression to better understand the relationships between digital skills and social and economic factors. This model's dependent variable was the proportion of individuals with basic or more advanced digital skills. In contrast, the independent variables included indicators such as early school leaving rates, PISA performance, and GDP per capita. This analysis aimed to identify those determinants that influence the development of digital

skills in the European Union member countries.

Principal component analysis (PCA) was used to facilitate the interpretation of the data, a technique that reduces the data's dimensionality without losing its essence. This method allowed the identification of the most relevant components that describe the data's variability and highlighted the correlations between digital skills and economic and educational indicators. PCA was essential to deepen the understanding of the data's structure and eliminate redundancies, thus facilitating interpreting the complex relationships between the variables.

4. Results and discussions

Between 2017 and 2022, the Digital Economy and Society Index (DESI) highlighted significant progress in the digitalization of European Union member states, reflecting their efforts to develop their digital infrastructure, the population's digital skills, and the adoption of emerging technologies in various economic sectors.

Nordic countries such as Denmark, Finland and Sweden have consistently held the top positions thanks to a combination of key factors: advanced digital skills among the population, state-of-the-art connectivity infrastructure and broad integration of digital technologies in the public and private sectors. For example, in Finland, the DESI score increased from 47.8 in 2017 to 69.6 in 2022, indicating a steady and accelerated evolution of digitalization (Figure 1). Similarly, Denmark and Sweden have maintained a steady growth rate thanks to strategic investments in infrastructure and national policies that encourage digital innovation.

The Netherlands, Ireland, and Luxembourg also ranked among the top countries, demonstrating remarkable adaptability to global technological change. The Netherlands benefited from a robust digital infrastructure and early adoption of advanced technologies in the business environment, while Ireland was boosted by the presence of multinational technology hubs and a highly digitally savvy workforce. Luxembourg stood out with its advanced connectivity infrastructure and business environment, which is friendly to digital innovations.

Romania, Greece, Bulgaria, and Poland have consistently been at the bottom of the DESI rankings. These countries have recorded lower scores due to underdeveloped digital infrastructure, lower levels of digital skills among the population and slower adoption of digital technologies in the public sector. For example, in Romania, the DESI score increased from 19.4 in 2017 to only 30.58 in 2022, remaining at the bottom of the ranking. Greece and Bulgaria have had similar developments, recording modest increases but insufficient to reduce the digital gap compared to the EU average.

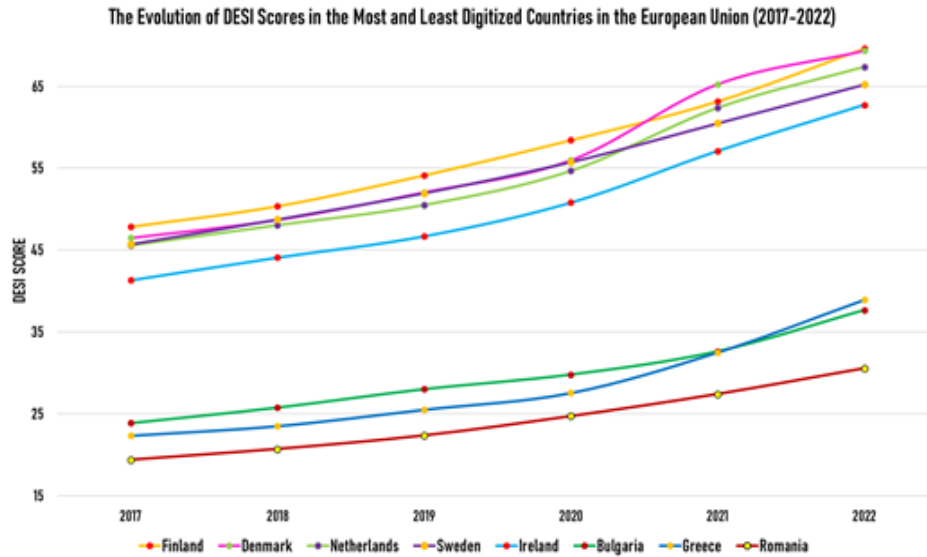


Figure 1. The Evolution of DESI scores in the most and least digitized countries in the European Union (2017-2022)

Source: own processing according Eurostat database, 2024.

A middle position was occupied by Latvia, which had a steady evolution, being close to the European average (Figure 2). With a DESI score of 37.4 in 2017 and 49.71 in 2022, Latvia has shown progress in digitalization but at a slower pace than the leading countries. This reflects a balance between developing digital infrastructure and the moderate digital skills of the population.

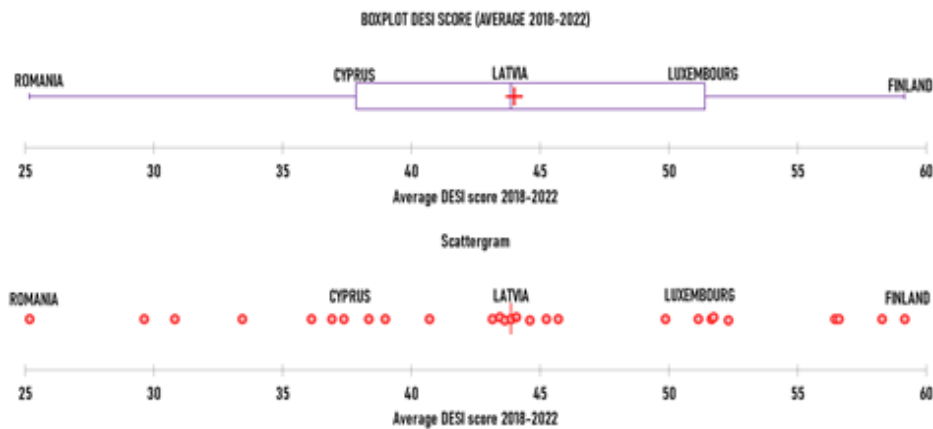


Figure 2. Boxplot DESI Score, Average 2018-2022)

Source: Ifimoaei & Vevera, 2024.

4.1 Boxplot analysis of social and economic indicators

In the context of global digitalization and new educational challenges, the analysis of educational and economic indicators in the European Union provides us with an overview of the social and economic factors that influence the digital skills of the population. The boxplots resulting from this analysis (Figure 3) reveal not only the disparities between the EU Member States, but also the visually observable correlations between the educational and economic levels and the development of digital skills.

The educational participation rate is a key indicator for understanding access to education and the capacity of education systems to prepare young people for the challenges of the digital economy. Countries such as Sweden and Denmark, with high educational participation rates, are more likely to have a workforce with strong digital skills. In contrast, in countries such as Bulgaria and Greece, with low participation rates, young people are at risk of not acquiring the skills needed to cope with the demands of the digital economy. This disparity suggests that a more inclusive and better-funded education policy is crucial to ensure the development of digital skills in all regions of the European Union.

The low performance of students in mathematics, especially in countries like Bulgaria and Greece, highlights another important dimension in the development of digital skills: STEM (Science, Technology, Engineering and Mathematics) education. Mathematical skills are fundamental for understanding and using digital technologies, and education systems that fail to improve these skills risk leaving a significant part of the population behind in the digitalization process. Thus, poor performance in mathematics is a predictor of lower digital skills, and investments in STEM education have become a priority to support the development of digital-ready human capital (Larson & Miller, 2011).

Economic indicators, such as real GDP per capita, bring to the fore another crucial dimension in the development of digital skills. EU Member States with robust economies, such as Luxembourg and Ireland, have a much more advanced digital infrastructure, which allows them to offer better opportunities for the development of citizens' digital skills. These countries are also able to invest more in education and continuing professional training, thus supporting the adaptation forced by rapid technological developments. On the other hand, in countries with low GDP, such as Romania, the lack of economic resources is reflected in limited access to quality education and in the reduced opportunities for the development of the population's digital skills. This underlines the importance of adopting economic and educational public policies that contribute to reducing the digital disparities between EU Member States.

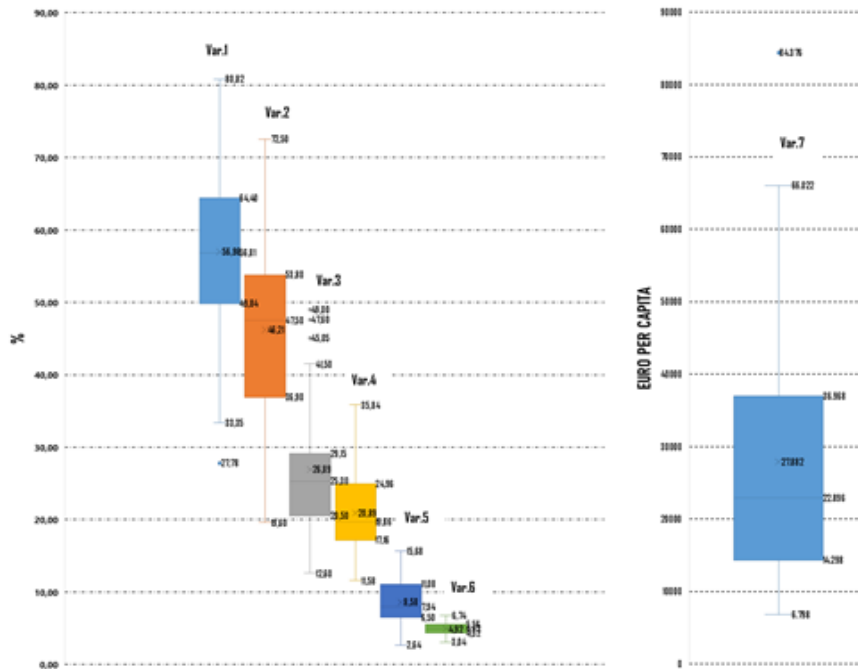


Figure 3. Boxplot analysis of socio-educational and economic indicators in EU Member States (2018-2022)

Source: own processing according Eurostat database, 2024.

Var 1. INDIC_avg_2021-2023

Var 2. Participation rate in education 2022

Var 3. Low achieving 15-year-olds math (PISA) 2018-2022

Var 4. AROPE 2018-2022

Var 5. Early leavers from education 2018-2022

Var 6. Education GDP % 2018-2022

Var 7. Real GDP per capita 2018-2022

4.2 Analysis of digital skills at European level: social and economic predictors

Digitalization plays an increasing role in everyday life and economic development. In this respect, digital skills have become a crucial indicator of the ability to adapt to new labour market requirements. In the analysis presented, data on the digital skills of the population in different EU countries provide a clear picture of the degree of preparation of citizens for the 4.0 Revolution challenges. These data are essential in shaping public policies that respond to the need for

continuous training of digital skills among the population, taking into account the social and economic context.

The first aspect that stands out is the significant disparity between EU Member countries in terms of the proportion of individuals with digital skills at a basic level or higher. For example, in countries such as the Netherlands (82.7%) and Finland (81.99%), the majority of the population has solid digital skills, reflecting not only investments in education and digital infrastructure but also a favourable economic context that supports the development of these skills. In contrast, countries such as Romania (27.73%) and Bulgaria (35.52%) have a much lower share of individuals with basic or higher digital skills, which suggests deficiencies in educational systems and a less developed digital infrastructure.

This difference highlights an important factor in the analysis of digital skills: the existence of a minimum "threshold" of skills required to actively participate in a digitalized society. Thus, countries with a higher percentage of people with basic or superior digital skills, such as Sweden (66.44%) and Finland, are in a better position to implement public policies that support the transition to more efficient digital economies. Conversely, countries with a higher share of individuals with limited or no digital skills, such as Romania and Greece, risk falling behind in the digitalization process, thus affecting not only the economic competitiveness but also the social integration of their citizens.

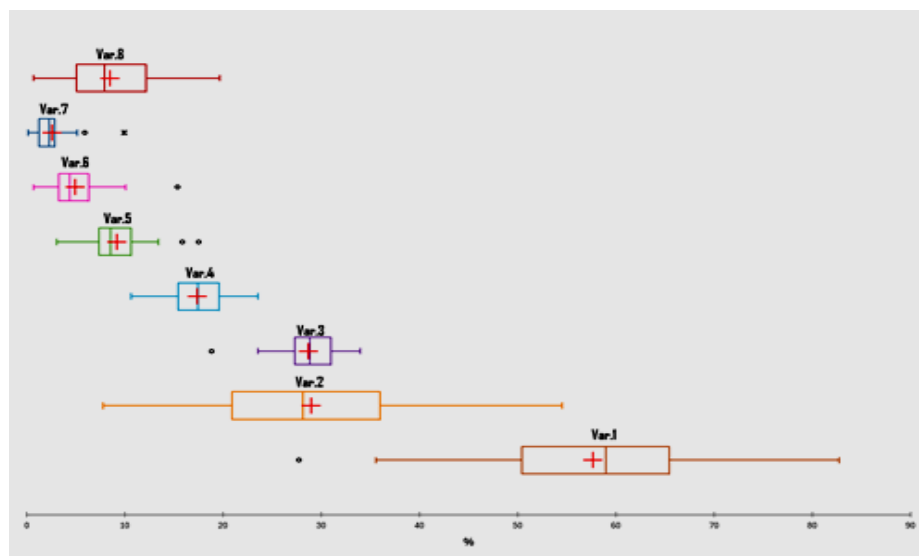


Figure 4. Level of Digital Skills in the EU Member States

Source: own processing according Eurostat database, 2024.

Another determining factor in this context is the educational level of the population and the economic resources allocated to education. Countries with developed economies, such as Germany and the Netherlands, have strong

educational systems that are capable of forming advanced digital skills among citizens. In contrast, countries with less developed economies, such as Romania and Bulgaria, face difficulties in ensuring equitable access to quality digital education, which contributes to the perpetuation of digital divides. This is a major challenge for the development of effective public policies that take into account the diversity of social and economic contexts in the European Union.

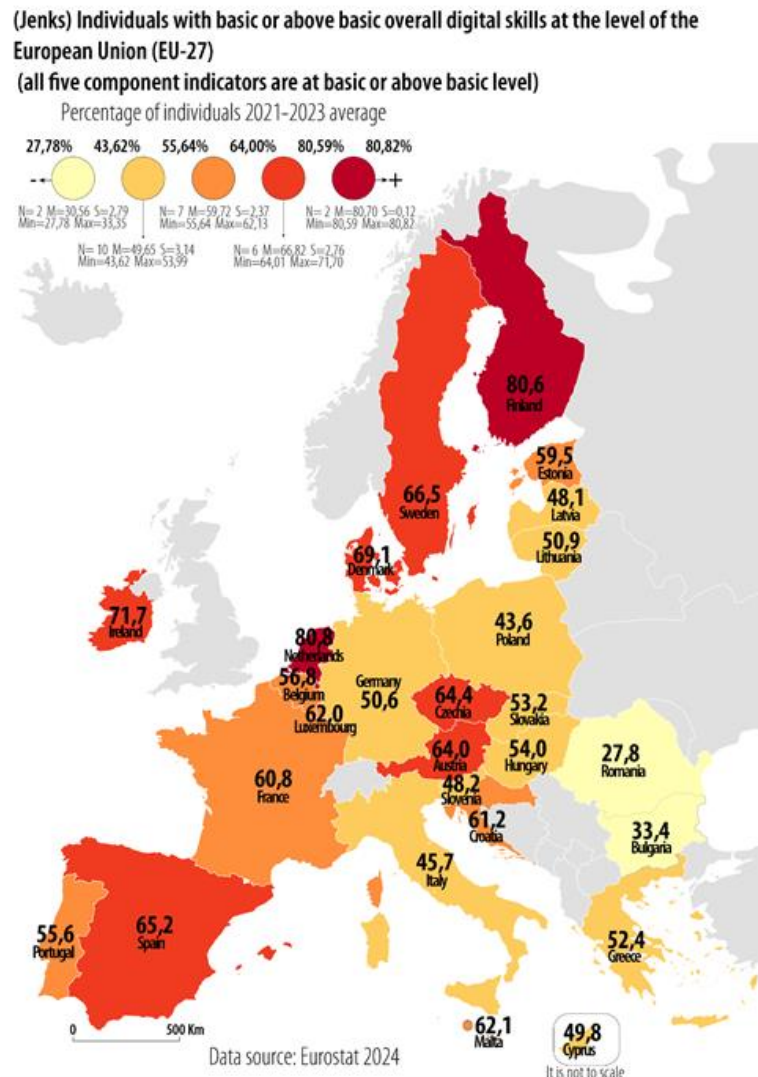


Figure 5. Individuals with basic or above basic overall digital skills at the level of the EU Member States

Source: own processing according Eurostat data, 2024.

4.3 Results of linear regression analysis

The quantitative analysis of the obtained data reveals a complex set of relationships between the different socio-economic variables and the level of digital skills, measured by the average `INDIC_avg_2021-2023`. The values of the coefficient of determination R^2 obtained from the regression of the variable `INDIC_avg_2021-2023` (0.6148) indicate that the model explains approximately 61.5% of the variation in digital skills, which suggests a significant correlation with the socio-economic factors analyzed (Figure 6).

From the correlation matrix, it is observed that the variable "AROPE 2018-2022" has a significant negative correlation with digital skills (`INDIC_avg_2021-2023`), having a coefficient of -0.6071. This indicates that a higher rate of risk of poverty and social exclusion is associated with a lower level of digital skills. Similarly, the variables "Low achieving 15-year-olds math (PISA)" and "Early leavers from education" also have negative correlations, respectively -0.5922 and -0.2957, with digital skills, which underlines the importance of education in developing digital skills in young people (Figure 7).

Var 1. `INDIC_avg_2021-2023`

Var 2. Participation rate in education 2022

Var 3. Low achieving 15-year-olds math (PISA) 2018-2022

Var 4. AROPE 2018-2022

Var 5. Early leavers from education 2018-2022

Var 6. Education GDP % 2018-2022

Var 7. Real GDP per capita 2018-2022

In terms of positive impact, "Participation rate in education 2022" is positively correlated with `INDIC_avg_2021-2023` (0.6378), suggesting that higher participation in education is associated with higher levels of digital skills. Also, "Real GDP per capita 2018-2022" has a moderate positive correlation (0.5786), indicating a link between economic prosperity and the development of digital skills.

The regression model of the variable `INDIC_avg_2021-2023` shows that "AROPE 2018-2022", "Low achieving 15-year-olds math (PISA)", and "Early leavers from education" have negative coefficients, suggesting that these variables have a reducing effect on digital skills. In contrast, "Participation rate in education 2022" and "Real GDP per capita 2018-2022" have positive coefficients, confirming the role of education and economic prosperity in improving digital skills. The coefficient for "Education GDP %" is, however, insignificant (0.4764), indicating that investment in education, measured by the percentage of GDP dedicated to education, does not have a significant impact on digital skills in this model.

Overall, the analysis suggests that socio-economic factors, such as education and GDP, significantly influence the level of digital skills, but there are also elements of social exclusion that reduce these skills.

Multicollinearity statistics:

	AROPE 2018-2-year-olds maths from education rate in ed/per capita 2on GDP % 2018-2022					
Tolerance	0,4058	0,5277	0,5564	0,3670	0,6557	0,6725
VIF	2,4643	1,8951	1,7973	2,7249	1,5250	1,4869

Regression of variable INDIC_avg_2021-2023:

Goodness of fit statistics (INDIC_avg_2021-2023):

Observations	27,0000
Sum of weights	27,0000
DF	20,0000
R2	0,6148
Adjusted R2	0,4992
MSE	74,9483
RMSE	8,6573
DW	2,4259

Analysis of variance (INDIC_avg_2021-2023):

Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	6	2392,4975	398,7496	5,3203	0,0020
Error	20	1498,9650	74,9483		
Corrected Total	26	3891,4626			

Computed against model Y=Mean(Y)

Figure 6. Linear regression results

Source: own processing according Eurostat database, 2024.

Correlation matrix (Pearson (n-1)):

Variables		Var.1	Var.2	Var.3	Var.4	Var.5	Var.6	Var.7
INDIC_avg_2021-2023	Var.1	1	-0,6071	-0,5922	-0,2957	0,6378	0,5786	0,3666
AROPE 2018-2022	Var.2	-0,6071	1	0,5756	0,4621	-0,5480	-0,3363	-0,4710
Low achieving 15-year-olds math (PISA) 2018-2022	Var.3	-0,5922	0,5756	1	0,3057	-0,5403	-0,3540	-0,4757
Early leavers from education 2018-2022	Var.4	-0,2957	0,4621	0,3057	1	0,0847	-0,1525	-0,1903
Participation rate in education 2022	Var.5	0,6378	-0,5480	-0,5403	0,0847	1	0,5158	0,3981
Real GDPper capita 2018-2022	Var.6	0,5786	-0,3363	-0,3540	-0,1525	0,5158	1	0,0842
Education GDP % 2018-2022	Var.7	0,3666	-0,4710	-0,4757	-0,1903	0,3981	0,0842	1

Values in bold are different from 0 with a significance level alpha=0,05

Figure 7. Pearson Corelation matrix

Source: own processing according Eurostat database, 2024.

4.4 The results of principal component analysis

The results of the principal component analysis (PCA – Figure 8) performed on the dataset comprising economic and social indicators reveal a clear structure of the factors contributing to the observed variability among the analyzed variables. The first principal component (F1) explains 50.42% of the total variability, followed by the second component (F2), which adds 16.64%. Together, these two components explain 67.06% of the diversity of the data, highlighting that a large part of the variability can be attributed to these two main dimensions.

The correlations between the individual variables and the principal components show a series of significant relationships. For example, "INDIC_avg_2021-2023" has a significant negative correlation with F1 (-0.8526), indicating that it negatively influences the first principal component. At the same time, "AROPE 2018-2022" shows a significant positive correlation with F1 (0.8200), which suggests a close link between social exclusion indicators and the general economic component.

As for the second principal component (F2), it explains 16.64% of the variability and shows significant correlations with variables such as "Low achieving 15-year-olds math (PISA) 2018-2022" (0.7982) and "Early leavers from education 2018-2022" (0.7873). This suggests that F2 reflects an educational dimension related to low school performance and school dropout, two important aspects of the education system.

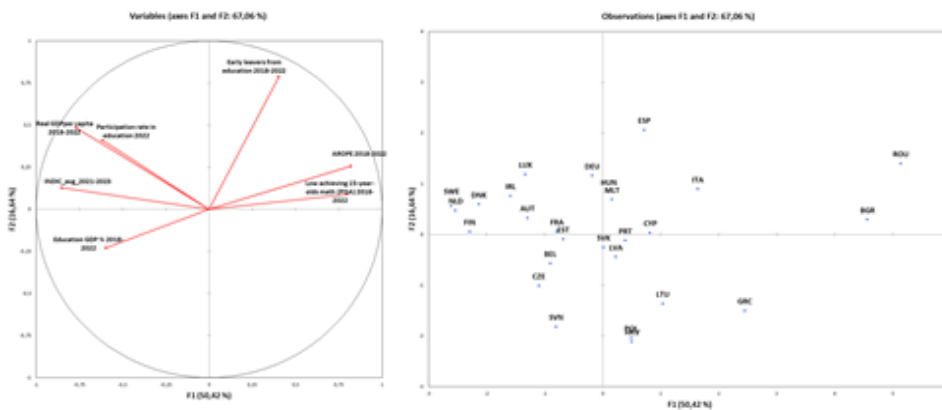


Figure 8. Principal Component Analysis

Source: own processing according Eurostat database, 2024.

The additional factors (F3, F4, F5, etc.) explain increasingly smaller proportions of the total variability, but continue to add relevant information about the various interactions between economic and educational indicators. F3, for

example, is associated with “Low achieving 15-year-olds math” and “Real GDP per capita”, indicating a link between economic and educational performance at the national level.

These results suggest that there is a significant interdependence between economic and socio-educational indicators, which underlines the importance of an integrated approach in public policy. Economic variables, such as GDP per capital and the percentage of GDP dedicated to education, are strongly correlated with educational performance, while socio-economic factors, such as the social exclusion rate, are associated with lower educational outcomes.

5. Conclusions

Multivariate statistical analysis performed in our study highlighted the complex interactions between economic and socio-educational indicators, suggesting that public policies should be oriented towards simultaneously improving economic and educational performance to support the sustainable development of society. The disparities observed between EU Member States draw attention to the importance of strategic investments in digital infrastructure, digital literacy, ICT education and training, and the promotion of technological innovations in public administration, the business sector, non-governmental organizations, culture, sport and leisure. While the Nordic countries and Western Europe dominate the DESI ranking, the countries of Eastern and Southern Europe need to accelerate the pace of reforms to reduce the digital disparities and benefit from the opportunities of the global digital economy.

Analyzing the evolution of the DESI score, it is estimated that, by 2030, the percentage of Romanian citizens with basic digital skills will reach 38%, which means an annual increase of approximately 1%. Public policy documents show that to reach the 50% target, an average annual increase of 3.1 percentage points would be necessary. In order to reduce the digital skills gap between Romania and the EU Member States, it is necessary to achieve the objectives set by public policies in digitalization (Eurostat, 2023).

Currently, a series of European and government-funded programs are being implemented focused on the training and development of digital skills, both in public administration and in the business environment. Older people are also included in the target groups of digital skills training projects, especially those carried out by private sector organizations/enterprises. The results of the implementation of these public policies will be evaluated annually through qualitative (independent research centers and academia) and quantitative (Eurostat - DESI Index; National Institute of Statistics) research, such as people's access to information and communications technology, continuous professional training in

enterprises, research and development in the public and private sectors, in order to see progress in relation to the assumed targets.

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Flipping the grade: Empowering students through self-assessment in informatics

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Abstract: *This paper illustrates how self-assessment and self-grading in Informatics education transform traditional grading into an active learning process. By shifting the focus from teacher-driven evaluation to student-led reflection, self-grading fosters autonomy, metacognition, and problem-solving skills. The paper shows how structured approaches – such as rubric-based self-grading, peer-reviewed assessment, and digital portfolios – enhance students' ability to critically evaluate their work and develop computational thinking. However, challenges such as grading reliability, student bias, and the need for structured guidance must be addressed. The paper highlights strategies to mitigate these issues, including standardized rubrics, justification mechanisms, and moderation through peer and teacher reviews. It demonstrates how balancing student autonomy with oversight ensures fairness and deepens engagement. By embedding self-regulation into assessment, the “Flipping the Grade” model shifts grading from a static measure to an iterative learning process. This paper presents self-grading as a powerful tool in competency-based Informatics education, fostering independence, accountability, and lifelong learning skills.*

Keywords: Self-assessment, Self-grading, Assessment criteria, Informatics, Active learning.

1. Introduction

Assessment has traditionally been a teacher-controlled process, where students receive grades based on external evaluations rather than their understanding of their learning progress. However, there is a growing shift towards student-driven self-assessment in modern education (McMillan & Hearn, 2008; Yan, Chiu & Ko, 2020; Gutu, 2022a; Wong & Taras, 2022; Gutu, 2023b), where learners actively evaluate and grade their work (Andrade, 2008; Weiss, 2018; Carroll, 2020; Panadero et al., 2023). This shift is particularly relevant in Informatics education, where problem-solving, debugging, and optimising code require continuous self-reflection and iterative improvement.

Implementing structured self-assessment models helps students develop critical thinking, self-regulation, and a deeper understanding of Informatics

concepts. This paper explores various models for integrating self-assessment and self-grading into Informatics education, including rubric-based evaluation, peer-reviewed self-grading, and digital portfolios. The focus is on how teachers can implement these models effectively, ensuring that students assess their work accurately and engage in meaningful self-reflection to enhance their programming skills.

2. Theoretical framework

“Flipping the Grade” is an innovative approach that transforms assessment from a teacher-centred practice into a student-led process. Instead of relying solely on teacher-assigned grades, students are provided explicitly stated assessment criteria and scoring indicator rubrics to evaluate their work, reflect on their learning, and assign themselves a grade based on their performance. This approach aligns with competency-based education, which emphasises the attainment of skill mastery rather than reliance on rote memorisation. Additionally, it aligns with the flipped learning model (Gutu, 2023a), which fosters student autonomy by encouraging learners to take an active role in their educational development.

The foundation of “Flipping the Grade” lies in constructivist learning theories, which emphasise the role of learners as active participants in their education. Constructivism posits that knowledge is actively constructed rather than passively received, meaning that students learn best when reflecting, self-regulation, and problem-solving. In Informatics education (Caspersen et al., 2022; Gutu, 2022b, 2023a), where students work with complex problem-solving tasks, algorithms, and debugging, critically evaluating one's work is crucial for developing computational thinking skills.

Metacognition, closely linked to constructivism, refers to the ability to reflect on one's thinking and learning processes. When students are engaged in self-assessment and self-grading, they actively practice metacognitive regulation (Giraldo & Herold, 2023; Nechyporuk & Romaniuk, 2024), a crucial component of independent learning. In Informatics education, particularly in programming, learning extends beyond the correct execution of syntax; it requires strategic problem-solving, logical reasoning, and continuous self-monitoring. According to Gutu (2022a, 2023a), students cultivate self-regulated learning skills through structured self-assessment, enabling them to plan their approach to programming tasks, monitor their progress, and assess their outcomes. These competencies are not only fundamental for academic achievement but also essential for long-term adaptability (Westover, 2024) and professional growth in technological fields (Verano-Tacoronte, Bolívar-Cruz & González-Betancor, 2015).

Moreover, self-grading within the flipped learning paradigm further amplifies student engagement and autonomy. In a flipped classroom model (Gutu, 2023a; Xia, 2023; Deng, Feng & Shen, 2024), theoretical instruction is delivered outside the classroom through digital resources, allowing in-class time devoted to

active problem-solving and applied learning. Extending this model to the grading process reinforces students' responsibility for their learning by requiring them to critically assess their work, identify areas for improvement, and assign themselves a grade based on provided assessment criteria (Stevens & Levi, 2005; Gutu, 2022a). This approach aligns with competency-based education, prioritising mastery of skills over accumulating grades. By self-grading, students transition from a fixed mindset, where assessment is seen as an endpoint, to a growth-oriented perspective, wherein evaluation is viewed as an iterative improvement process. Rather than perceiving grades as static indicators of ability, students develop a reflective mindset emphasising continual skill refinement.

According to Gutu (Gutu, 2022a), the effectiveness of self-assessment and self-grading in Informatics education is contingent upon providing clear and structured assessment criteria. The absence of explicit grading guidelines may result in inaccurate self-evaluation (Dixon et al., 2020), either due to overestimating one's abilities or an undue lack of confidence in one's work. Teachers must employ structured rubrics that define specific evaluation parameters (Andrade, 2008; Muhammad, Lebar & Mokshein, 2018), including code correctness, efficiency, readability, debugging methodologies, and problem-solving approaches to mitigate such inconsistencies. These rubrics serve as objective benchmarks, ensuring student evaluations align with established learning objectives and maintaining consistency across self-assessments.

In addition to rubrics, guided reflection prompts enhance the depth of self-assessment by prompting students to justify their evaluations. Reflection questions (e.g., "What were the primary challenges I encountered while coding?" "How does my solution compare to alternative approaches in terms of efficiency?" and "What modifications could improve my implementation?") encourage higher-order cognitive engagement.

By shifting the responsibility of assessment from teachers to students, the "Flipping the Grade" model fosters a learning culture centred on accountability, self-regulation, and lifelong learning. In Informatics education, continuous learning and adaptability are essential for success (Caspersen et al., 2022); this approach enhances students' technical competencies and cultivates critical thinking and self-directed learning behaviours. When implemented effectively, self-grading transforms traditional assessment into a dynamic and reflective learning process, equipping students with the skills necessary for both academic and professional excellence in computational fields.

3. Models of implementation for "Flipping the Grade" in informatics

3.1 Self-grading rubrics with assessment criteria and scoring indicators

Implementing self-assessment and self-grading in Informatics requires structured approaches that ensure both objectivity and student engagement. One of the most effective methods for guiding students in this process is the use of detailed

grading rubrics. As outlined by Stevens and Levi (2005), Brookhart (2013), Dawson (2017), and Muhammad, Lebar, and Mokshein (2018), rubrics are designed with distinct elements tailored to specific aspects of assessment, such as task-specific criteria, task descriptions, and analytic cumulative scoring. These elements aim to clarify the task, identify the level of mastery, and guide students through new concepts.

In this context, the self-grading rubric developed in this study provides students with explicit assessment criteria and scoring indicators, enabling them to evaluate their work effectively. This structured approach ensures that students comprehend key aspects of quality programming, including code correctness, readability, and debugging strategies. Furthermore, the assessment criteria facilitate critical analysis of students' coding practices and other Informatics-related activities, thereby fostering self-regulation (Andrade & Brookhart, 2016; Gutu, 2022a) and enhancing independent problem-solving skills.

The process of self-grading begins with the teacher designing a comprehensive description rubric that clearly defines the parameters for assessment. This rubric typically includes multiple dimensions of evaluation, such as functionality (whether the code produces the expected output), efficiency (how well the algorithm optimises computational resources), readability (the clarity and organisation of the code), and debugging (the student's ability to identify and correct errors). Before engaging in self-assessment, students receive explicit instruction on using the rubric, often through guided examples where they practice grading sample code snippets. This preparatory step ensures consistency and accuracy in the self-assessment process.

Once students have completed their programming tasks, they apply the rubric with descriptions to their work, carefully assessing each criterion. This process encourages them to critically reflect on their problem-solving approach, identifying strengths and areas for improvement (Andrade & Brookhart, 2016; Dawson, 2017; Muhammad, Lebar & Mokshein, 2018; Gutu, 2023b). To enhance accountability, students are required to justify their self-assigned grades through written explanations or brief verbal reflections. This justification process reinforces metacognitive skills and minimises the risk of inflated or inaccurate self-grading. By articulating the reasoning behind their evaluations, students become more conscious of the quality of their work and develop a deeper understanding of Informatics concepts.

Furthermore, students are encouraged not to refer to the assessment criteria before completing the task. They should only consult these criteria if they do not fully understand the task requirements. In this regard, within the same classroom, the same criteria can serve different purposes: either as a guide for task completion or as a tool for assessing the level of mastery. This approach fosters student engagement and promotes independent task execution.

An example of this implementation in an Informatics classroom involves a programming task focused on loop structures in C++. Students are assigned a task

that requires them to write a program utilising loops to perform a computational task (Table 1).

Table 1. Example of a problem statement

<p>The Bunker Access Code Puzzle</p> <p>A secret bunker conceals essential information in a deserted city of ruins and mysteries. To uncover the events in this city, a group of explorers has decided to enter the bunker and investigate its contents. Access to the bunker is restricted by a unique numerical code, which can only be deciphered by solving a mathematical puzzle left behind by the engineers of the previous civilisation. Engraved on the massive surface of the bunker door are n numbered panels, each containing a distinct number. These numbers serve as the key to decrypting the bunker’s access code.</p> <p>Puzzle Rules:</p> <ul style="list-style-type: none"> • Examine each panel and read the inscribed number. • Determine whether the given number is prime. • Sum all the prime numbers identified on the n panels to obtain the final sum. • The sum of the identified prime numbers represents the bunker’s access code. <p>Input Data:</p> <ul style="list-style-type: none"> • A natural number n, indicates the total number of panels. • n distinct natural values, each representing a number engraved on a panel. <p>Output Data:</p> <ul style="list-style-type: none"> • A natural number represents the sum of the prime numbers on the panels, constituting the bunker’s access code. <p>Constraints and Specifications:</p> <ul style="list-style-type: none"> • $1 \leq n \leq 100$ • $2 \leq \text{engraved value on a panel} \leq 1000000$
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After writing and debugging their code, students assess their performance using the assessment rubrics (Table 2). They evaluate whether their loops execute correctly, whether their algorithm is optimised for efficiency, their understanding of the problem statement, the correctness of summing prime numbers, the implementation of an optimised prime-checking function, input handling and adherence to constraints, and whether their code follows best practices for readability and clarity. They are encouraged to revise their work before finalising their self-assessment if they encounter errors. In addition to assigning a numerical grade, students provide a short reflection explaining how they arrived at their score, detailing any challenges they faced and the strategies they used to overcome them.

Table 2. Provided assessment criteria for the bunker access code solution

1.	Criteria: Input Handling and Adherence to Constraints	
	Excellent (20 pts)	Correctly processes all constraints, including boundary values (e.g., $n=1$, $n=100$, $2 \leq \text{engraved value on a panel} \leq 1000000$). Fully adheres to input rules and uniqueness conditions.
	Good (15 pts)	Handles most edge cases but overlooks one or two. Minor constraint issues (e.g., fails to enforce distinct values or mishandles $n=99$).
	Satisfactory (10 pts)	Manages some edge cases but fails in extreme cases. Partial constraint adherence (e.g., incorrect range handling).
	Needs improvement (5 pts)	Fails to manage boundary conditions, leading to errors. Do not enforce constraints, resulting in incorrect outputs.

2.	Criteria: Prime number identification	
	Excellent (20 pts)	Implements an optimised prime-checking function with $O(\sqrt{n})$ time complexity.
	Good (15 pts)	Correctly identifies primes but with minor inefficiencies (e.g., unnecessary divisibility checks, no separate function).
	Satisfactory (10 pts)	Partially correct implementation; some incorrect results for certain numbers (e.g., incorrectly classifies <i>one</i> or other <i>numbers</i> as prime).
	Needs improvement (5 pts)	Incorrect prime-checking logic, leading to significant errors (e.g., missing actual primes or misidentifying composites).
3.	Criteria: Summing prime numbers	
	Excellent (20 pts)	Correctly sums only prime numbers as required and ensures accuracy.
	Good (15 pts)	Works correctly but lacks efficiency (e.g., unnecessary checks or redundant calculations).
	Satisfactory (10 pts)	Some errors in summation (e.g., including non-primes or missing primes in the sum).
	Needs improvement (5 pts)	Incorrect or missing logic summation leads to completely wrong results.
4.	Criteria: Time complexity & Memory efficiency	
	Excellent (20 pts)	Implements prime checking with $O(\sqrt{n})$ complexity. Uses minimal and necessary memory without redundancy.
	Good (15 pts)	Efficient but with minor optimizations missing (e.g., redundant calculations, extra loop iterations). Slightly higher memory use but no major inefficiencies.
	Satisfactory (10 pts)	Uses a less optimal approach (e.g., checks divisibility up to n instead of \sqrt{n}). Unnecessary memory usage (e.g., storing extra data instead of direct processing).
	Needs improvement (5 pts)	Highly inefficient (e.g., nested loops, brute force checking). Excessive memory usage due to redundant storage or poor management.
5.	Criteria: Code clarity and readability	
	Excellent (10 pts)	Well-structured, properly indented, and includes meaningful variable names and inline comments explaining key sections.
	Good (8 pts)	Mostly clear, with minor readability issues (e.g., inconsistent spacing or some unclear variable names). Includes some comments.
	Satisfactory (5 pts)	Somewhat readable but lacks consistent formatting. Does not include comments.
	Needs improvement (2 pts)	Poorly structured, making it difficult to follow. No comments, making it hard to understand the logic.
6.	Criteria: Understanding of the problem statement	
	Excellent (10 pts)	Clearly understands the problem and implements all requirements correctly, including constraints and conditions.
	Good (8 pts)	Demonstrates good understanding but misses minor details (e.g., slight deviations in expected input/output format).
	Satisfactory (5 pts)	Basic understanding, but some requirements are incomplete or misinterpreted (e.g., incorrect assumption about the number range).
	Needs improvement (2 pts)	Major misunderstanding of the problem, an incorrect or incomplete implementation that does not align with the given statement.
Total Score: /100 Points		
90 - 100: Outstanding implementation with correct logic, efficiency, and clarity.		
75 - 89: Good implementation with minor efficiency or edge case handling issues.		
50 - 74: Satisfactory but with noticeable logic, efficiency, or constraints errors.		
Below 50: Needs significant improvements in correctness, efficiency, and understanding.		

The assessment criteria in rubrics can be presented more explicitly by incorporating concrete aspects of code development, using specific code sequences to support students' understanding. This approach is particularly useful when introducing students to a new topic or concept. Alternatively, the criteria can be presented in a less detailed manner, as shown in Table 2, to encourage a more critical self-evaluation process. This type of approach requires a final collective analysis to ensure that all students have correctly applied and assessed their work using these criteria.

The selection of approach depends on the desired level of competency mastery in student development. When the criteria are used frequently, aspects related to *Code Clarity and Readability*, *Time Complexity & Memory Efficiency*, *Input Handling*, and *Adherence to Constraints* tend to be implicitly considered by students, thereby streamlining the self-evaluation process and reducing the time required for assessment.

To enhance the efficiency of the assessment process, these evaluation rubrics can be implemented online using platforms such as Google Forms, Microsoft Forms, Moodle, or any other system that enables automated score calculation. Additionally, these platforms allow students to review their selected responses for further reflection and reevaluation. Consequently, the option to complete the rubrics multiple times could be enabled to foster continuous learning and improvement.

Therefore, this model fosters a greater sense of responsibility and engagement among students. Rather than viewing assessment as an external judgment imposed by the teacher, students take ownership of their learning process, recognising assessment as a personal and academic growth tool. Furthermore, this approach aligns with competency-based education by emphasising skill mastery over task completion. Students develop an iterative mindset by repeatedly engaging in self-assessment, refining their problem-solving techniques and enhancing their programming abilities.

3.2 Peer-reviewed self-grading model

The peer-reviewed self-grading model is a structured approach that integrates collaborative assessment with self-reflection, fostering a deeper engagement with learning while promoting accuracy in self-assessment. Unlike traditional grading, where the teacher solely determines evaluation, this model introduces a two-step verification process: peer feedback (Topping, 2018; Gutu, 2022a) and self-grading based on structured reflection. This process strengthens students' ability to analyse their work critically and that of their peers, encouraging constructive dialogue, iterative improvement, and metacognitive awareness in Informatics education (Gutu, 2023a, 2023b).

The implementation of this model begins with students exchanging their programs before assigning themselves a grade. The exchange ensures that each

student evaluates a peer's work using teacher-provided assessment criteria. This stage encourages students to apply their analytical skills to a peer's program, providing structured feedback highlighting strengths and improvement areas. Peer feedback is a formative checkpoint (Kumar, Kenney & Buraphadeja, 2013; Simonsmeier et al., 2020), offering an external perspective that may uncover unnoticed errors or suggest optimisations that enhance code efficiency. Furthermore, peer assessment develops communication and critique skills (Double, McGrane & Hopfenbeck, 2020), which are essential for collaborative problem-solving in Informatics.

Following peer feedback, students return to their programs, reviewing the suggestions received before conducting their self-assessment. This reflection phase allows students to revise their code, address logical errors, improve structure, or optimise functionality. Once revisions are complete, students proceed with self-grading, assigning themselves a score based on the same rubric used for peer evaluation. This step requires them to justify their grade, explaining how their program aligns with the provided criteria and what changes were made based on peer feedback. The requirement for justification reinforces accountability and self-regulation, ensuring that students engage deeply with the assessment process rather than arbitrarily assigning grades.

An example of this model in practice can be illustrated through a sorting algorithm task. A student initially submits an implementation of bubble sort and exchanges it with a peer. The peer identifies that while the algorithm produces correct output, its efficiency could be improved by reducing unnecessary iterations. They provide this feedback, suggesting the optimised version with an early termination condition. Upon receiving the input, the students revisit their code, incorporate the proposed improvement, and re-evaluate their work. They then assign themselves a grade, justifying their decision by explaining how the peer feedback led to a more efficient implementation.

This iterative process of peer review, revision, and self-grading enhances students' ability to critically engage with their work while developing a more accurate understanding of evaluation criteria. It also reduces grading bias, as self-assessment is informed by both external feedback and assessment criteria reflection. By shifting the grading process from a teacher-centric activity to collaborative and self-directed practice, this model empowers students to take ownership of their learning and fosters a culture of continuous improvement in Informatics education.

3.3 Digital portfolios with self-grading reflections

In the context of Flipping the Grade, digital portfolios serve as an effective tool for fostering self-assessment, metacognition, and long-term learning reflection (Yancey, Cambridge & Cambridge, 2023) in Informatics education. Unlike traditional grading methods, which offer students only a final score with limited

feedback, digital portfolios provide a structured way to document their coding progress, evaluate their work, and justify their grading decisions over time. This process enhances student autonomy and encourages continuous improvement by allowing learners to revisit their past work, identify patterns in their learning, and develop a growth mindset.

To implement self-grading through digital portfolios, students maintain an organised collection (Bergebál Vázquez et al., 2021) of their coding exercises, challenges, and projects, each accompanied by a self-assessment reflection. The structure of these portfolios typically includes three key components: the initial problem statement or task, the student's solution (code and/or algorithm), and a self-reflection entry where they analyse their performance based on predefined grading criteria. The self-reflection component is crucial, as it requires students to critically evaluate their strengths, weaknesses, debugging strategies, and overall approach to problem-solving. Students engage in deeper cognitive processing by assigning and justifying their grades, reinforcing their understanding of Informatics concepts and programming logic.

In our educational practice, we utilize Moodle and Google Classroom for managing digital portfolios, providing a structured framework for student reflection and self-assessment. Within this process, teachers assume a facilitative role, offering periodic feedback on students' reflections rather than assigning direct grades to their work. Comments provided on the platform focus on the accuracy of self-assessment, the depth of reflection, and areas requiring improvement, rather than merely validating or correcting student-assigned grades. The primary objective is to support students in developing evaluative judgment, enabling them to accurately assess their performance over time. In cases where there is a significant discrepancy between a student's self-assigned grade and expected performance standards, teachers intervene through guided questioning or structured discussions rather than direct correction. This approach reinforces student responsibility and autonomy in the learning process.

A practical example of this implementation can be seen in project-based assessments, where students develop a mini-programming project aligned with specific learning objectives. As part of their portfolio, students document their development process, challenges encountered, and problem-solving approaches. Upon completing the project, they use a rubric or checklist provided by the teacher to assess their work, assigning themselves a grade based on parameters such as functionality, efficiency, code readability, and debugging quality. In their reflection, they justify their grade by addressing key questions: Did the program meet the intended goals? What were the main challenges? How did I improve my code? What would I do differently in a future iteration? This iterative process promotes self-directed learning and continuous improvement, enabling students to develop a more sophisticated understanding of programming principles.

The use of digital portfolios for self-grading has significant pedagogical advantages (Berbegal Vázquez et al., 2021; Domene-Martos et al., 2021; Yancey, Cambridge & Cambridge, 2023). First, it shifts the focus from external validation to intrinsic motivation, as students become active participants in their assessment rather than passive recipients of grades. Second, researchers highlight that the digital portfolio provides a comprehensive record of student learning, allowing both students and teachers to track progress, identify learning gaps, and make informed instructional adjustments (Chang et al., 2018; Berbegal Vázquez et al., 2021). Finally, this approach aligns with modern competency-based education models, where assessment is not solely about correctness but also about the process of learning, problem-solving, and self-regulation.

By integrating self-grading through digital portfolios, teachers can create a more reflective and autonomous learning environment in Informatics. Students are assessed not only on their final output but also on their ability to evaluate and improve their work. This model ensures that grading is not an endpoint but an ongoing learning process, preparing students to be self-reliant and critical thinkers in their future academic and professional pursuits.

4. Challenges and considerations

The integration of self-grading in Informatics education offers significant benefits in fostering autonomy, metacognitive skills, and critical thinking. However, its implementation is accompanied by challenges that must be carefully addressed to ensure fairness, accuracy, and pedagogical effectiveness. Key concerns include grading reliability, balancing student autonomy with teacher oversight, and providing structured guidance to facilitate accurate self-assessment.

A primary challenge in self-grading is the risk of inaccurate assessment due to over- or underestimation of one's abilities. Without clear evaluation criteria, students may inflate or deflate their grades, leading to inconsistencies that compromise the reliability of assessments. Establishing detailed, standardized rubrics with explicit performance indicators mitigates this risk, enabling students to align their evaluations with objective benchmarks rather than personal biases. Additionally, incorporating justification mechanisms, such as reflective explanations or comparative analysis with exemplars, enhances grading accuracy by encouraging deeper metacognitive engagement.

Balancing student autonomy with teacher oversight is another critical consideration. While self-grading promotes student ownership of learning, the absence of teacher intervention may result in discrepancies or manipulation of grades. A moderation system, where teachers review a subset of student-assigned grades, ensures consistency while maintaining student agency. Furthermore, peer assessment serves as an intermediary validation step, allowing students to refine their self-assessment based on external feedback. A multi-layered approach – integrating self, peer, and moderated teacher assessments – preserves fairness while reinforcing evaluative skills.

Effective self-grading implementation necessitates explicit scaffolding strategies. Self-assessment is a learned skill, requiring structured guidance and modeling. Teachers should introduce self-evaluation techniques through demonstrated grading exercises, allowing students to practice using rubrics with sample work before applying them to their own assignments. Collaborative discussions and peer comparisons further refine evaluative abilities by exposing students to diverse perspectives on quality and performance standards. Iterative self-assessment, wherein students engage in repeated grading cycles with feedback-driven refinement, cultivates more reliable self-evaluation practices over time.

Ultimately, the success of self-grading in Informatics education depends on a well-structured framework that addresses grading biases, ensures an appropriate balance of autonomy and oversight, and fosters the development of self-assessment competencies. By embedding reflective evaluation into learning processes, students not only enhance their ability to critically assess their programming work but also cultivate essential problem-solving and self-regulation skills necessary for academic and professional growth. This structured approach positions self-grading as a transformative tool in competency-based education, shifting assessment from a static grading mechanism to an iterative learning process.

5. Conclusions

Implementing self-assessment and self-grading in Informatics education carries significant pedagogical implications, particularly in transforming students' perceptions of grading. Traditionally, students view grades as external judgments imposed by teachers, often prioritizing high scores over the learning process itself. By engaging in self-assessment, grading becomes an active, reflective learning experience rather than a summative evaluation. This shift fosters deeper cognitive engagement, requiring students to critically analyze their work, justify their assessments, and identify areas for improvement. Rather than passively receiving grades, they develop a growth-oriented mindset where feedback and self-reflection become integral to their learning. In Informatics education, where problem-solving and debugging demand iterative thinking, this approach strengthens students' ability to independently evaluate their coding practices and enhance their computational skills over time.

Beyond fostering a mindset shift, self-grading cultivates responsibility and accountability by requiring students to apply structured assessment criteria to their work. This process enhances self-regulation, an essential skill in programming and software development. When students justify their self-assigned grades using predefined rubrics, they engage in metacognitive evaluation, improving their ability to detect errors, optimize solutions, and critically assess their problem-solving approaches. Moreover, by assuming responsibility for their grading, students become more invested in the quality of their work, leading to increased motivation and engagement. This approach also reduces dependency on teacher

validation, fostering independence and self-confidence in their programming abilities.

The “Flipping the Grade” approach redefines assessment practices in Informatics education by encouraging a shift in student mindsets and reinforcing self-regulation skills. By integrating self-assessment and self-grading, teachers can cultivate a more autonomous, reflective, and engaged learning environment that better prepares students for the demands of computational problem-solving and lifelong learning.

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Determination of the Artificial Intelligence readiness levels of pre-service teachers

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Abstract: *This study aims to determine “the artificial intelligence readiness levels of pre-service teachers”. The research, which is based on the quantitative data collection method, was conducted with 247 “pre-service teachers”, and examined whether the gender, age distribution and type of program they study create a significant difference in their artificial intelligence readiness levels. The results obtained from the research, “pre-service teachers” have high awareness of artificial intelligence readiness levels. Another result obtained from the study is that “the gender, age distribution and type of program” “don’t create a significant difference” in their artificial intelligence readiness levels. It is recommended that “the artificial intelligence readiness levels of pre-service teachers” should be examined in larger groups by considering other variables.*

Keywords: teacher education, teacher training program, pre-service teacher, artificial intelligence, AI.

1. Introduction

Artificial Intelligence (AI) has stepped in the field of education not before it entered other areas such as economics, finance, and banking; thus, it can be argued that it is manifested in every area of life today (Ayanvale et al., 2024). In literature, “artificial intelligence is defined as the ability of a system to correctly interpret external data, learn from these data, and use what it has learned to achieve specific goals and tasks through flexible adaptation” (Kaplan & Haenlein, 2018). One of the points emphasized by most authors is that artificial intelligence systems exhibit behaviors that are indistinguishable from humans in every respect, and have “cognitive, emotional, and social intelligence” (Haenlein and Kaplan, 2019). “Artificial intelligence includes the ability of a system to perceive data or to control, move, and change objects based on the information learned, and in this

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respect, it is a broader concept than machine learning” (Kaplan and Haenlein, 2018). Artificial intelligence systems are divided into three groups by Kaplan & Haenlein (2018): (1) “*Analytical AI*” covers features equal to cognitive intelligence. AI systems in this group create “*a cognitive representation of the world and use previously learned information to make future decisions*”. (2) “*Human-Inspired AI*” is equal to “*cognitive and emotional intelligence*”. AI systems in this group can understand human emotions along with cognitive intelligence and use them in decision-making processes. Finally, the AI systems that have not yet been developed are described as (3) “*humanized AI and include all characteristics such as cognitive, emotional, and social intelligence*”. Artificial intelligence systems have an undeniable impact on world education systems on a global scale. It is considered a necessity to display effective AI literacy and skills today in order for teachers and students to interact with AI in their future lives (Zhai et al., 2021; Chiu & Sanusi, 2024). It is for this reason that countries and policy makers should carry out the necessary reforms in education systems, and arrangements should be made “to create a positive school climate” where the symbiosis of teachers, students, school administrators and AI systems can flourish.

Zhang et al. (2023) state that the rapid development of the usage of artificial intelligence technologies will change the nature of in-class training radically and highlight the importance of learning and teaching processes. Teachers are now in the process of assuming a new role with their new partners, namely the artificial intelligence systems, which will share the responsibility for teaching. This rapid change requires a revision of the pedagogy regarding the role of teachers in university teaching (Popenici & Kerr, 2017; Zhai et al., 2021). Teachers need to think about where they will use AI systems in their curriculum to teach students the terminal behaviors. They also need to think about how and for what purposes they will use these systems. Teachers and teacher educators must acquire the relevant competencies on how to integrate AI systems into the objectives, content, learning experiences and assessment stages, which are the elements of their curriculum. Teachers are among the most important stakeholders that influence the development of AI literacy behaviors and skills of students (Chiu & Sanusi, 2024). The aim of this study is to determine “*the readiness levels of pre-service teachers for artificial intelligence*”. To achieve this aim, answers are sought to the following questions:

1. “What is the readiness level of pre-service teachers for artificial intelligence?”
2. Do the following factors make a significant difference in AI readiness levels?
 - 2.1. “Gender,
 - 2.2. Age,
 - 2.3. Type of program of the pre-service teacher”.

2. Method

This study preferred the quantitative method. Pre-service teachers from an academy that trains teachers in the north of Cyprus participated in the study. Data were collected on a “voluntary” basis at the academy where a total of 327 “pre-service teachers” are enrolled. In this context, 247 “pre-service teachers” participated in the study, 170 of whom are female (68.8%) and 76 of whom are male (30.8%), whereas 1 “pre-service teacher” did not specify his/her gender. 146 of “the pre-service teachers” are between the ages of 18-20 (59.1%), and 101 of them (40.9%) are 21 years old and above. 197 of “the pre-service teachers” are studying in the classroom teaching department (79.8%) and 50 of them are enrolled in the preschool teaching department (20.2%).

In order to achieve the research purpose, the “AI Readiness Scale for Preservice Teachers” scale (2024) was used, which was adapted into Turkish by Özüdođru and Yildiz Durak. The “5-point Likert-type scale was scored from 5 (Strongly Agree) to 1 (Strongly Disagree)”. It can be stated that as the scores obtained from the scale approach 5, the readiness levels of “pre-service teachers” for artificial intelligence increase positively. The scale consists of “18 items” and “4 sub-dimensions” as “cognition, ability, vision and ethics in teaching”. After obtaining the necessary permission for the use of the Turkish adaptation scale (Özüdođru & Yildiz Durak, 2024), the data collection process was planned. The researchers filed an application to the ethics committee of the relevant institution, and having received the necessary permission they met with the “pre-service teachers”. The data collection process was carried out via Google Form. The participant “pre-service teachers” were first informed about the purpose of the study, then the relevant link was shared with them, and they were asked to answer each scale item sincerely and accurately. The application of the scale took approximately 10-15 minutes for each participant. All information about the participants was kept confidential by the researchers.

The data obtained from the research were analyzed in the “SPSS package program”. The distribution of “pre-service teachers according to their gender, age and the type of program” was calculated with frequency and percentage values, whereas the levels of readiness for artificial intelligence were found with Mean and standard deviation values. “One-Sample Kolmogorov-Smirnov test” was used to determine whether the data showed “normal distribution”. The findings revealed that the data did not comply with a “normal distribution” ($p < 0.05$), therefore Nonparametric tests were preferred in the study. “Mann Whitney U test” was resorted to analyze whether there was a “significant difference” in the levels of artificial intelligence readiness of “pre-service teachers” according to their “gender, age, and program type”. “Cronbach's Alpha reliability” coefficient of the data obtained from the research was calculated as .945, which shows that the obtained data has a high level of reliability.

3. Results

3.1 Artificial Intelligence readiness level of pre-service teachers

Table 1 presents the findings obtained from the scale applied to “*determine the readiness levels of pre-service teachers for artificial intelligence*”.

Table 1. Mean Score of “Readiness Level of pre-service teachers for Artificial Intelligence”

Artificial Intelligence readiness level	N	Minimum	Maximum	Mean	Std. Deviation
Cognition	247	1,00	5,00	3,9466	,75809
Ability	247	1,17	5,00	3,9750	,78019
Vision	247	1,33	5,00	4,0040	,77534
Ethics	247	1,00	5,00	3,8850	,84695
Total score	247	1,33	5,00	3,9518	,68789

“*The AI readiness levels of the pre-service teachers*” were generally within the limits of “*I agree*” (M=3.95, SD=.687). Similarly, the readiness levels of the “*pre-service teachers*” for the cognition sub-dimension (M=3.94, SD=.758), as well as ability (M=3.97, SD=.780), vision (M=4.00, SD=.775) and ethics (M=3.88, SD=.846) sub-dimensions were also within the limits of “*I agree*”. The “*vision*” sub-dimension has the highest average score. These results reveal that the readiness of “*the pre-service teachers*” for the use of AI technologies in education is at a high level. The findings reveal that “*pre-service teachers*” are aware of the importance of artificial intelligence, can organize teaching environments with artificial intelligence technologies, know the strengths and limitations of artificial intelligence, and comprehend the relevant ethical responsibilities.

3.2 Artificial Intelligence readiness levels of pre-service teachers by gender

The artificial intelligence readiness levels of “*pre-service teachers according to their gender*” were analyzed using the “*Mann Whitney U test*”. Table 2 provides the findings obtained.

Table 2. Artificial intelligence “readiness levels of pre-service teachers by gender”

Sub-dimensions	Gender	N	Mean Rank	Sum of Ranks	U	P
Cognition	Female	170	119,99	20397,50	5862,500	,244
	Male	76	131,36	9983,50		
Ability	Female	170	122,58	20839,00	6304,000	,761
	Male	76	125,55	9542,00		

Vision	Female	170	121,25	20613,00	6078,000	,453
	Male	76	128,53	9768,00		
Ethics	Female	170	120,74	20526,50	5991,500	,360
	Male	76	129,66	9768,00		
Total	Female	170	120,09	20414,50	5879,500	,260
	Male	76	131,14	9966,50		

Table 2 shows that “*the gender of the pre-service teachers*” does not create a “*significant difference*” in their readiness levels for artificial intelligence (U=5879.500; p=.260; p>0.05). An examination of the findings manifests that “*no significant difference*” was found in “*the readiness levels of female and male pre-service teachers*” regarding the “*cognition*” (U=5862.500; p=.244; p>0.05), “*ability*” (U=6304.000; p=.761; p>0.05), “*vision*” (U=6078.000; p=.453; p>0.05) and “*ethics*” (U=5991.500; p=.360; p>0.05) dimensions. The findings also reveal that the gender variable does not create “*a significant difference*” for “*pre-service teachers*” in their awareness of the importance of artificial intelligence, usage of artificial intelligence in teaching processes, knowledge of the strengths and limitations of artificial intelligence, and understanding of ethical responsibilities.

3.3 Artificial Intelligence readiness levels of pre-service teachers by age

“*The Mann Whitney U test*” was used to analyze whether the age variable created “*a significant difference in the artificial intelligence readiness levels of pre-service teachers*”.

Table 3. Artificial Intelligence readiness level by age variable

Sub-dimensions	Age	N	Mean Rank	Sum of Ranks	U	P
Cognition	18-20	146	119,70	17476,00	6745,000	,252
	21 and above	101	130,22	13152,00		
Ability	18-20	146	116,90	17067,50	6336,500	,059
	21 and above	101	134,26	13560,50		
Vision	18-20	146	121,17	17690,50	6959,500	,448
	21 and above	101	128,09	12937,50		
Ethics	18-20	146	119,03	17378,00	6647,000	,185
	21 and above	101	131,19	13250,00		
Total	18-20	146	117,80	17198,50	6467,500	,101
	21 and above	101	132,97	13429,50		

Table 3 shows that “*the age of the pre-service teachers*” does not create a “*significant difference*” in their readiness levels for artificial intelligence (U=6467.500; p=.101; p>0.05). The findings obtained from the research revealed that the age variable does not create “*a significant difference in the readiness levels*”

of the pre-service teachers” for the “cognition” dimension (U=6745.000; p=.252; p>0.05) and the “ability” (U=6336.500; p=.059; p>0.05), “vision” (U=6959.500; p=.448; p>0.05) and “ethics” dimensions (U=6647.000; p=.185; p>0.05).

3.4 Artificial Intelligence readiness levels of pre-service teachers by program type

The study examined whether the program type of “the pre-service teachers explain a significant difference” in their readiness levels for artificial intelligence. Table 4 shows the findings obtained from “the Mann Whitney U analysis test”.

Table 4. Artificial Intelligence readiness level by program type

Sub-dimensions	Program type	N	Mean Rank	Sum of Ranks	U	P
Cognition	Classroom teaching	197	123,24	24277,50	4774,500	,737
	Preschool	50	127,01	6350,50		
Ability	Classroom teaching	197	126,30	24881,00	4472,000	,313
	Preschool	50	114,94	5747,00		
Vision	Classroom teaching	197	126,13	24847,00	4506,000	,347
	Preschool	50	115,62	5781,00		
Ethics	Classroom teaching	197	123,18	24266,50	4763,500	,718
	Preschool	50	127,23	6361,50		
Total	Classroom teaching	197	124,88	24600,50	4752,500	,702
	Preschool	50	120,55	6027,50		

According to the findings obtained from the research, “the program type of the pre-service teachers” does not cause “a significant difference” in their readiness levels for artificial intelligence (U=4752.500; p=.702; p>0.05). In a similar vein, the type of program does not create a significant difference in their readiness levels for the “cognition” dimension (U=4774.500; p=.737; p>0.05), as well as “ability” (U=4472.00; p=.313; p>0.05), “vision” (U=4506.000; p=.347; p>0.05) and “ethics” (U=4763.50; p=.718; p>0.05) dimensions.

4. Discussions and conclusions

This study, which aimed to determine “the readiness levels of pre-service teachers for artificial intelligence”, found high levels of readiness for the participants. It revealed that “pre-service teachers” have “a high vision for artificial intelligence technologies” and believe that they can undertake “the relevant ethical responsibilities”. The results revealed that “pre-service teachers” are aware of the importance of using “artificial intelligence technologies” in education. The

importance of teacher training programs to be designed in a way that will equip “pre-service teachers” with the use of “artificial intelligence technologies” in education becomes evident.

The study also examined whether “gender, age, and program type” created a significant difference in “artificial intelligence readiness levels”. The results revealed that “gender”, “age distribution”, and the “type of program” of “pre-service teachers” did not create “a significant difference” in terms of their “artificial intelligence readiness levels”. In their study conducted with “pre-service teachers”, Kalnina et al. (2024) concluded that age, gender, and level of education did not create a significant difference in the perception of artificial intelligence. Mart and Kaya (2024), in their study with “pre-service teachers”, did not find a significant difference between the attitudes of “pre-service teachers” towards artificial intelligence and their literacy levels according to gender, and they concluded that there was “no significant difference” between the age groups in terms of positive attitudes of “pre-service teachers” and artificial intelligence literacy. Their finding supports the results of this study.

It is recommended that more research should be conducted on the use of artificial intelligence technologies in teacher education and that variables other than gender, age, and program type should be examined. It is also suggested that researchers focus on studies that will develop teacher training programs supported by “artificial intelligence technologies” and test their effectiveness.

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Advancing education management through integrated CRM solutions leveraging the scalability and efficiency of a distributed web systems architecture

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Abstract: *Integrating customer relationship management (CRM) solutions into educational management processes offers a potential for transformation in the management of student engagement, administrative tasks, and instructional delivery. This paper explores the conceptual design of a distributed web platform that leverages CRM technologies to improve educational outcomes. Using a modular and scalable architecture, the proposed system aims to enable efficient data management, real-time communication, and personalized learning experiences. The study addresses key technical challenges such as system interoperability, data security, and scalability, and discusses potential solutions based on next-generation computing and cloud services. The proposed framework highlights how distributed CRM-based platforms can revolutionize traditional educational management models by promoting a more responsive and adaptable learning environment. The insights provided serve as a foundation for future development and empirical evaluation, guiding educational institutions in the strategic implementation of CRM systems to improve student satisfaction, streamline administrative processes, and support innovative teaching methods.*

Keywords: Education Management, CRM Solutions, Distributed Web Platform, Student Relationship Management, Educational Technology, Web-Based Education, E-Learning Systems, CRM Integration.

1. Introduction

The fast development of digital technologies is drastically changing how schools are run. As a result, schools are implementing new tools that can get students more involved, make administrative tasks easier, and give each student a very personalized learning experience (Khneyzer, Rebeiz & Touma, 2025). In this context, Customer Relationship Management (CRM) solutions are proving to be a strategic asset for educational institutions that want to modernize their operations

and develop stronger connections with students, faculty, and administrative staff. Although CRM systems are traditionally used in the business environment for customer relationship management, they can be easily adapted to meet the unique needs of the educational environment, focusing on student lifecycle management, academic advising, and personalized communication strategies (Bahaddad, 2025).

Software known as customer relationship management systems is designed to manage customer relationships in a way that improves communication, personalization of services, and optimization of internal processes with the aim of improving customer satisfaction and loyalty (Georgieva-Trifonova, Petrov & Milev, 2023).

As educational processes become increasingly digitalized and distributed, there is a growing need for scalable and interoperable platforms that can manage diverse data sources and integrate diverse actors in the educational ecosystem (Popescu, Ileana & Bold, 2024). A distributed web platform using CRM technologies offers an opportunity to transform the way educational services are designed, delivered, and managed. Such platforms facilitate seamless communication between students and educators, provide data-driven insights for decision-makers, and enable adaptive teaching strategies that respond to individual learning needs (Ileana, 2023a).

The integration of blockchain technology into educational certification processes ensures a transparent, secure, and verifiable record of acquired knowledge. This approach proposes an architecture for awarding degrees that streamlines the validation of academic competencies and reduces the possibilities for fraud in the graduation process (Ileana & Popgeorgiev, 2024).

In the context of the modernization of educational systems, the integration of CRM solutions into distributed web architectures offers a promising perspective for streamlining institutional management. Such a general approach involves essential architectural considerations, such as modularity, scalability, and security, necessary for building robust systems (Basri & Hasri, 2024). Issues of interoperability between various systems, protection of data confidentiality and security, and ensuring optimal performance within distributed networks arise (Anghel, Ianc, Ileana & Modi, 2020). Addressing these essential aspects highlights the potential of CRM-based platforms to optimize decision-making processes, allocate resources efficiently, and improve the experience and satisfaction of users, including students.

A recent study on distributed web systems addresses energy efficiency strategies and optimization methods, highlighting the importance of reducing energy consumption without compromising performance. These insights can be integrated into research on CRM solutions in a distributed web architecture, suggesting potential synergies between optimizing energy resources and streamlining educational management (Ileana, 2023b).

2. Literature review

Research led by De Juan-Jordán examines the design and functionality of customer relationship management systems tailored for higher education institutions (HEIs). These systems are essential to meet the evolving expectations of students, faculty, alumni, and donors while enhancing relationships, operational efficiency, and personalized experiences. The study highlights key CRM features such as lead tracking, personalized communication, and social media integration, supporting the entire student lifecycle, from recruitment to alumni engagement. Future trends include the adoption of artificial intelligence for predictive analytics and personalized recommendations, the integration of social CRM to engage digitally native generations, and the use of chatbots to automate tasks and improve communication efficiency. These advances position CRM systems as indispensable tools for higher education institutions in the digital age (Juan-Jordán, Guijarro-García & Hernández-Gadea, 2018).

A study by Miake et al. developed a Customer Knowledge Management (CKM) model for higher education institutions (HEIs), based on the integration of Customer Relationship Management and Knowledge Management (KM) practices. The model aims to improve student relationship management by centralizing and analyzing data from diverse sources, such as demographic, academic, financial, and behavioral information. This process allows for the personalization of interactions and the development of effective strategies to increase student engagement and retention. The study provides empirical validation of the CKM model, testing it on a group of over 600,000 students from a large private higher education group in Brazil. The results showed a significant improvement in re-enrollment rates among students exposed to personalized campaigns, compared to a control group that did not benefit from such interventions. Key factors supporting the model's success include precise data segmentation, which allows for the personalization of messages and offers based on each student's circumstances, the use of advanced IT infrastructures, such as business intelligence tools and data mining techniques, and managerial alignment. The authors emphasize that successful implementation requires not only technological solutions, but also a change in organizational culture and the integration of CKM into the strategic objectives of institutions (Miake et al., 2018).

The explores the role of social media marketing and customer relationship management in sustaining competitive advantage and increasing student loyalty in private higher education institutions. Focusing on five faculties at Budi Luhur University in Jakarta, the study incorporated a sample of 110 students and used structural equation modeling (SEM) to analyze the data. Findings highlight that competitive advantage mediates the impact of CRM on student loyalty but does not serve as a mediator between social media marketing and loyalty. Existing literature emphasizes the importance of developing their needs in order to develop innovative strategies that stimulate loyalty. Several studies align with this by

demonstrating that social media marketing influences business loyalty and competitive advantage through its ability to create difference. Similarly, it has been shown that CRM enhances organizational objectives, maintains student satisfaction, and sustains competitive advantages in various contexts. However, this research identifies inconsistencies, especially in the education sector, where the direct impact of social media marketing on loyalty and competitive advantage remains limited. This gap highlights the importance of personalized approaches in private universities to optimize student interactions. Institutions need to focus on creating their social media campaigns and CRM practices, such as promoting personalized experiences and leveraging technological advances to meet student expectations. By addressing these aspects, universities can not only secure competitive advantages but also strengthen emotional bonds, ultimately improving student loyalty and success in the marketplace (Usino & Murtiningsih, 2019).

3. Methodology

The section explores the conceptual approach for integrating Customer Relationship Management solutions into a distributed web architecture, focusing on the technical and functional benefits of this integration. The methodology adopted uses software engineering principles, task distribution technologies, and CRM-specific processes to develop a scalable and robust framework for the educational environment (Tajiddinovna, 2024).

3.1 CRM in education

Primarily developed to help companies manage customer relationships, CRMs are flexible and robust software platforms that have evolved greatly to adapt to the needs of a variety of industries and sectors, such as public administration, healthcare, and education. They rely on the collection, organization, and analysis of data, which allows organizations to better understand customer needs and provide more personalized services (Khneyzer, Rebeiz & Touma, 2025).

The adoption of new technologies and the need to respond to the increasingly diverse demands of contemporary society have caused a profound transformation of education. In this context, advances such as smart learning and virtual reality offer new perspectives for adapting educational processes to the dynamic needs of the labor market (Ileana & Marian, 2024).

In the educational context that is in a continuous development and integration of new technologies, CRMs play a central role in managing the complex relationships between students, teachers, and administrative staff (Kumar & Reinartz, 2018). They function as a centralized system that manages to integrate and coordinate information related to academic performance, educational preferences, administrative interactions, and institutional communication. Among the essential functionalities are (Khanna, 2019):

- **Communication personalization:** By using historical data and user preferences, CRMs allow messages to be tailored to individual needs, thus improving the efficiency of communication between students and the institution;
- **Academic Progress Monitoring:** CRM systems collect and analyze information about student performance in real time, providing detailed reports to teachers and educational counselors. This supports early identification of problems and personalized interventions;
- **Automate management-related procedures:** Processes such as enrollment, course scheduling, issuing certificates, or managing payments are simplified by CRM, which saves time and resources;
- **User behavior analysis:** By monitoring interactions and usage patterns, CRMs can identify emerging trends or needs, allowing the institution to respond proactively.

Technologically, CRMs rely on relational databases and advanced data analytics systems to generate actionable insights (Ghaus-Pasha, 2024). These platforms are typically scalable, allowing for the integration of large volumes of data and supporting a large number of users. In addition to standard functionalities, modern CRMs use emerging technologies such as (Gupta & Agarwal, 2024):

- **Machine learning:** Machine learning algorithms allow CRMs to analyze patterns in data and make personalized recommendations. For example, students can receive suggestions for courses or educational resources based on their interests and past performance;
- **Predictive analytics:** CRMs can anticipate potential problems, such as the risk of school dropout, and generate alerts for early interventions;
- **Integration with learning platforms:** CRM systems are often compatible with e-learning platforms, providing an integrated and seamless educational experience.

In addition to technological advantages, CRMs contribute to the transformation of operational processes, reducing redundancy, improving productivity, and optimizing resource allocation (Potla & Pottla, 2024). In the educational environment, these benefits are essential to meet the increasingly complex demands of students and to support the development of a modern and adaptable educational environment (Pitafi & Mumtaz, 2024).

Educational institutions are improving user experience by integrating these systems and improving their ability to adapt to changes in the global educational landscape. Consequently, CRMs are becoming a vital tool in the digitalization and modernization of educational management (Shukla & Pattnaik, 2019).

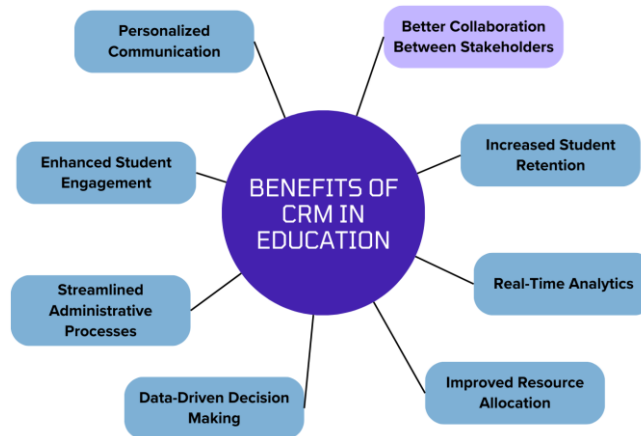


Figure 1. Impact of CRM systems on educational processes

Figure 1 presents a clear and structured vision of the benefits of using Customer Relationship Management systems in education. The central element highlights the role of CRM in improving educational processes and experiences, and each branch represents a specific benefit associated with the use of these systems:

- Personalized Communication - CRM allows for the personalization of communication between the institution and students, offering messages and solutions adapted to the needs and preferences of each user;
- Enhanced Student Engagement - Increases student involvement by monitoring their behavior and offering resources and support according to their interests;
- Streamlined Administrative Processes - Automates administrative processes such as enrollment, issuing certificates, or scheduling courses, saving time and resources;
- Data-Driven Decision Making - The integration of real-time analysis supports informed decision-making based on data collected from educational activities;
- Improved Resource Allocation - Contributes to the efficient allocation of the institution's resources, ensuring that they are directed to the areas that have the greatest impact;
- Real-Time Analytics - Enables continuous data analysis to identify problems and opportunities, helping to optimize the institution's performance;
- Increased Student Retention - Monitors academic progress and student behavior to prevent dropouts and support educational success;

- Better Collaboration Between Stakeholders - Facilitates collaboration between students, faculty, and administrative staff, improving workflows and communication.

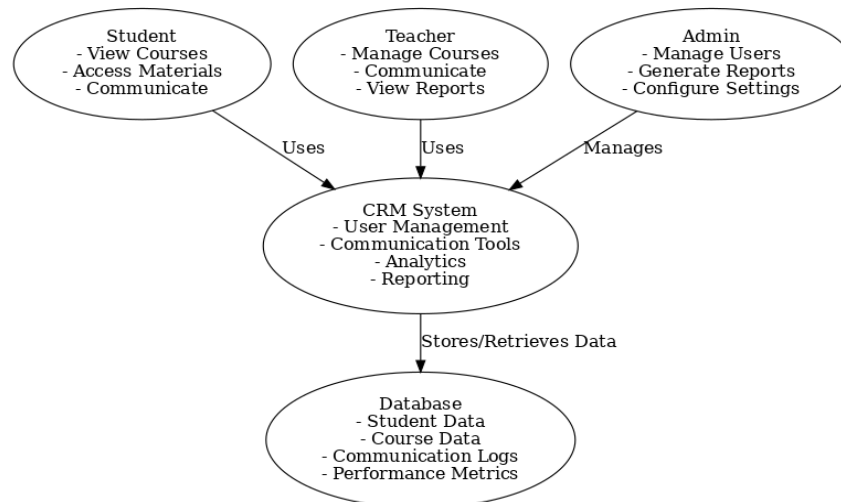


Figure 2. Diagram of a CRM system for education

Figure 2 illustrates a diagram of a CRM system for use in education, representing the main components and the relationships between them. A centralized database is connected to the CRM system and stores vital information such as performance metrics, communication history, and student and course data. Interaction with the database shows the process of storing and retrieving information, and the relationships between the user and the system show how each person uses or manages the CRM components. The diagram highlights three types of users: Student, Teacher, and Admin, each with specific roles and functionalities within the system:

- The student interacts with the CRM system to access courses, educational materials, and communicate with teachers and peers;
- The teacher uses the system to manage courses, communicate with students, and analyze performance reports;
- The administrator manages users, configures system settings, and generates detailed reports on user activity and performance.

To ensure the efficient implementation of these systems in the educational environment, modern technologies such as web frameworks (Node.js, Django), scalable databases (PostgreSQL, MongoDB), and cloud services (AWS, Azure) can be used. Additionally, existing CRM solutions like Salesforce Education Cloud and Microsoft Dynamics 365 can be adapted to enhance academic and administrative processes, providing customized solutions for student relationship management and educational resource optimization.

3.2 Distributed web system architecture

Distributed web systems are infrastructures in which software components are distributed among multiple nodes that collaborate to execute complex tasks (Ileana, 2023a). Offering redundancy, dynamic scalability, and high availability, they are essential for managing data and a large number of users. A distributed architecture allows for real-time load management, reducing response times and ensuring service continuity in the educational environment, where digital platforms are very widespread (Sivakumar et al., 2025).

Technical features include (Veeramachaneni, 2025):

- Load balancing: Evenly distributing loads among nodes to prevent overloading a single server;
- Fault tolerance: The ability to continue operating in the event of a node or component failure;
- Vertical and horizontal scalability: The ability to add new hardware resources or expand the system capacity by adding new nodes.

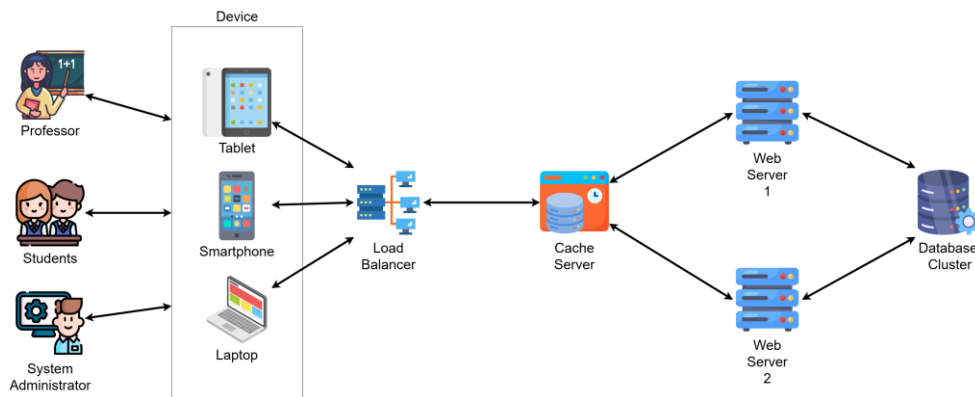


Figure 3. Distributed Web system architecture for CRM in education

Figure 3 represents the architecture of a distributed web system integrated with an education CRM, highlighting the main components and the data flows between them. Arrows highlighting the path of user requests from their devices to servers and databases represent the data flows. This architecture creates a powerful environment for users and educational institutions, emphasizing scalability, modularity, and efficiency in managing educational resources and relationships.

This architecture is designed to optimize user relationship management and provide an efficient and scalable educational experience:

- User Devices: The system includes devices used by educational actors, such as tablets, smartphones, and laptops, connected to the system through a common interface. Teachers, students, and system

administrators use these devices to interact with the platform;

- **Load Balancer:** It acts as a central point for traffic management, distributing user requests to the appropriate servers to ensure optimal performance and availability;
- **Cache Server:** It allows the temporary storage of frequently used data, reducing access time and the load on web servers;
- **Web Servers:** Web servers process user requests that are not available in the cache, providing access to system functionalities and relevant data;
- **Database Cluster:** It stores central data, including information about users, courses, and communication. Web servers access the cluster to obtain data when needed.

4. Results and discussions

Combining a CRM software platform with a distributed web architecture offers significant benefits, transforming the way educational institutions manage processes and interactions. In a CRM on a distributed architecture, data is stored and processed on multiple nodes, which allows:

- **Increased operational efficiency:** Processes are automated and supported by the distributed infrastructure, which ensures fast response times and optimized performance.
- **Increased security:** Data distribution between nodes reduces the risk of information loss and allows the implementation of advanced encryption and controlled access policies.
- **Advanced personalization and analysis:** Data collected through CRM can be analyzed in real time using advanced algorithms, which allows for the personalization of educational resources and the optimization of the user experience.

The integration of these technologies also allows for the expansion of system functionality without significant disruption, a crucial advantage in dynamic educational environments. For example, a distributed system can simultaneously support an online learning platform and an enrollment administration module without compromising on user performance.

5. Conclusions

Integrating CRM solutions into distributed web architectures is a strategic approach to modernizing educational management. This combination allows educational institutions to leverage the distinct technological advantages offered by each component, improving overall operational efficiency and optimizing the user

experience, which is the most important element in the context of these platforms. CRM solutions contribute to personalizing educational processes, managing complex student relationships, and automating administrative tasks, while distributed architectures ensure scalability, redundancy, and robust performance.

The study highlights that this technological integration facilitates the use of real-time analytics, machine learning, and interoperability, which creates a flexible and adaptable educational environment. Distributed architectures also improve system security and reliability, efficiently managing large amounts of data and users.

By implementing these technologies, educational institutions will be prepared and better able to respond to modern challenges, promoting innovative teaching methods, data-driven decision-making, and user satisfaction. These conclusions provide a solid foundation for future research aimed at empirically assessing the impact and exploring additional technological solutions for improving educational management.

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Avatars and Artificial Intelligence in education: A bibliometric analysis

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Abstract: *This study presents a bibliometric analysis of research on avatars and artificial intelligence (AI) in education using data from the Web of Science. A total of 189 articles were analyzed with WOS viewer to identify key trends, influential authors, frequently used keywords, and global research distribution. The findings indicate that China, the USA, and Germany are leading contributors. The most frequently used keywords include "artificial intelligence," "metaverse," "virtual reality," and "avatar," reflecting a strong focus on immersive learning technologies. Citation analysis highlights influential authors such as Graesser, Dwivedi, Wang, and Yee. Additionally, the study explores alignment with Sustainable Development Goals (SDGs), particularly Goal 3 (Good Health and Well Being). By mapping research patterns and gaps, this study provides insights for scholars, educators, and policymakers to enhance the integration of avatars and AI in education, ensuring effective and inclusive learning environments.*

Keywords: Artificial intelligence, Avatar, Bibliometric analysis, Education, Immersive learning.

1. Introduction

Artificial intelligence (AI) and avatar integration in education are revolutionizing instruction by improving accessibility personalization and engagement (Rizvi, 2024). While AI-driven tools personalize instruction automate tasks and provide real-time feedback avatars as digital representations encourage motivation and teamwork. Even though there is growing interest in this area the studies that are currently available are frequently dispersed and concentrate on particular applications rather than offering a thorough global synthesis.

By performing a bibliometric analysis that methodically maps the research landscape on avatars and AI in education, this study adds to the body of literature. In contrast to earlier research that looks at discrete features of these technologies, this study offers a comprehensive viewpoint by examining worldwide patterns identifying significant writers and publications and emphasizing new themes.

Empirical insights are provided beyond narrative reviews by utilizing bibliometric techniques offering a data-driven understanding of the evolution of the field (Halim et al., 2024; Kniňová, 2024).

Examining how research on avatars and AI aligns with the Sustainable Development Goals (SDGs) of the United Nations especially Goal 4 (Quality Education) and Goal 3 (Good Health and Well-Being) is a significant innovation of this study. The role of AI and immersive technologies in education has been recognized by earlier research but their wider societal impact and contribution to global educational goals have received less attention (Beecken, 2024). By filling in this gap our research not only charts the fields intellectual framework but also emphasizes its applicability to educators and policymakers looking to integrate AI and avatars into inclusive and productive learning settings.

This is accomplished by addressing five major research questions: (1) How is research on avatars and AI in education distributed across countries? (2) What are the most commonly used keywords? (3) Who are the most cited authors? (4) What are the most common words in abstracts? (5) Which SDGs are most referenced? By addressing these questions, fresh perspectives on the development of this field of study will be offered to point out knowledge gaps and suggest future research directions.

By providing a methodical and data-driven viewpoint this current study bridges the gap between artificial intelligence immersive learning and educational policy making it especially pertinent. The research will help academics, educators and policymakers make more informed decisions about incorporating AI and avatars into educational frameworks by providing a better understanding of the direction of this fields research. By demonstrating the originality and value of the work considerable contribution will be made to the understanding of how emerging technologies function in education.

2. Method

2.1 Article selection process

In this study, bibliometric mapping analysis was used. In order to carry out the bibliometric mapping analysis, the literature source was selected as Web of Science. Using the advanced search function, the keywords entered were “Avatar” AND Education” AND “Artificial Intelligence” in the all-field section. A total of 191 published articles relating to the use of Avatar in education were accessed (Access date: February 2025). When English was selected as language, and the document type was limited to articles, book chapter, proceeding papers, and review articles, the number obtained was 189. Then, full records and cited references were downloaded in plain text file format. The file was uploaded to the VOSViewer software.

2.2 Data analysis

Bibliometric analysis illustrates the most recent research patterns within a specific research framework (Kacprzak & Hensel, 2023). Bibliometric research can demonstrate the visualization of intellectual structures using network mapping specific to a research field with important themes which can then help to clarify and discover future research related to a particular research field (Wen et al., 2021).

3. Findings

3.1 Distribution of articles across countries

In order to create a map based on text data for the distribution of the number of articles across countries, the Web of Science bibliographic database file was uploaded into the programme. Then, the field for the minimum number of citations was set as 20. Of the 57 countries, the largest set of connected items that met the criteria were found to be 13. The map created from this is shown in Figure 1. It shows 13 items, 3 clusters, and 56 links and total link strength 116.

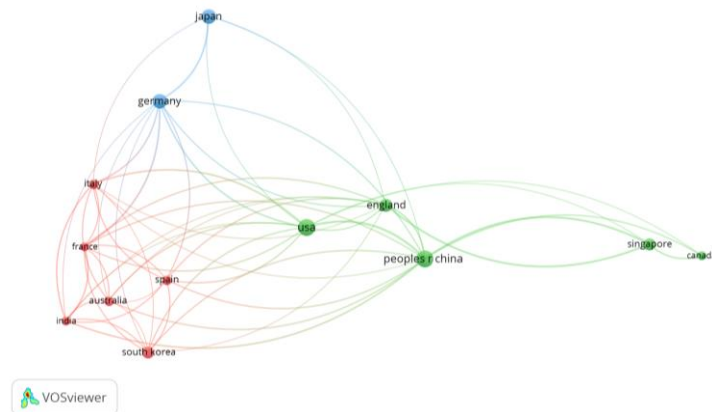


Figure 1. Distribution of articles across countries

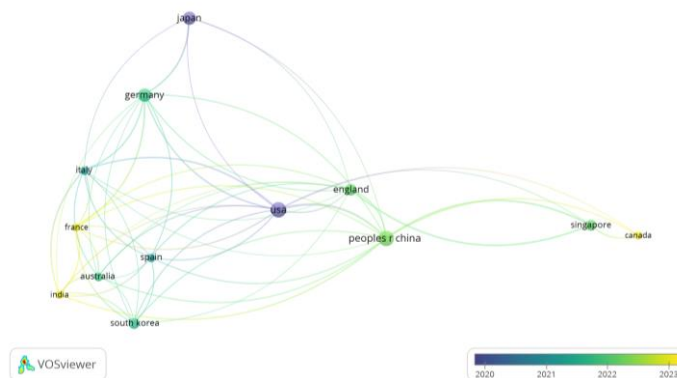


Figure 2. Distribution of the number of articles across countries by year

Table 1. Countries

Country	Documents	Citations	Total link strength
China	37	1568	31
Usa	35	1055	26
Germany	25	941	23
Japan	25	55	8
England	18	961	21
Singapore	16	561	14
South Korea	15	1155	14
Australia	10	967	14
Italy	10	907	19
Spain	10	1068	17
India	8	1104	18
Canada	7	265	6
France	7	1063	21

3.2 Most used keywords in the articles

In order to create a map based on text data for the most used keywords, co-occurrence analysis was used and author keywords were selected. The minimum number of occurrences of a keyword was set as 5 and the number of keywords to be selected was automatically given as 11. The map created is illustrated in Figure 3. It shows there are two clusters and the most used keyword is 'artificial intelligence' ($f = 38$). In addition, it is revealed that 'metaverse' ($f = 30$), 'virtual reality' and 'avatar' ($f = 28$) each, 'avatars' ($f = 16$) and 'augmented reality' ($f = 14$) are the most used keywords. These results indicate that the articles mostly focus on artificial intelligence and metaverse. It can be seen that AR studies in science education began to grow in number in 2013, though the first study was published in Web of Science much earlier, in 1999. When the distribution of the number of articles using the keywords by year is shown, it can be seen that recent articles focus mainly on mobile learning. The distribution of the number of the articles by years is presented in Figure 3.

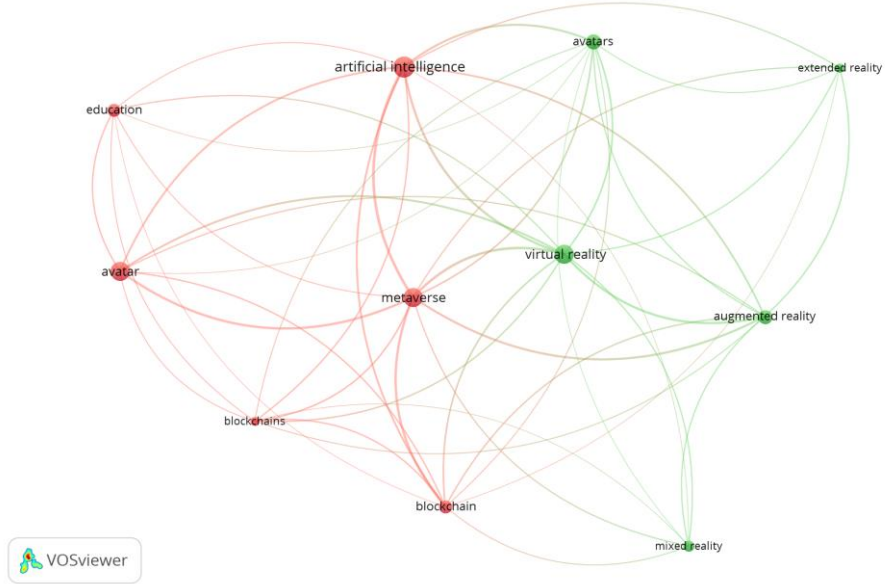


Figure 3. Most used keywords in the articles

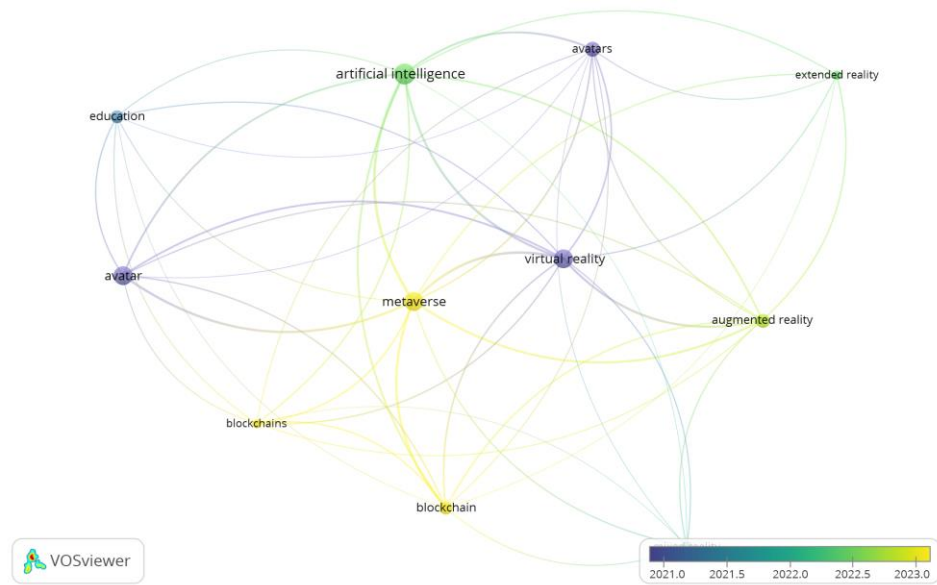


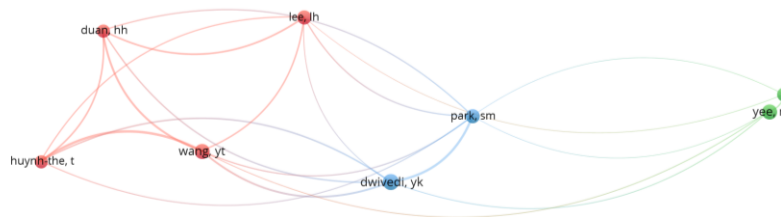
Figure 4. Author keywords by year

Table 2. Co-occurrence of author keywords

Keyword	Occurrences	Total link strength
Artificial intelligence	37	62
Metaverse	30	75
Avatar	29	39
Virtual reality	28	62
Avatars	16	30
Augmented reality	14	44
Blockchain	11	41
Education	11	15
Mixed reality	7	14
Blockchains	5	26
Extended reality	5	16

3.3 Most cited authors

In order to create a map for most cited authors, citation analysis and cited authors were selected. The minimum number of citations of an author was set as 10. The map created is shown in Figure 5. This indicates that Graesser, Ac (18 citation) Dwivedi, Yk (16 citation), Wang, Yt (14 citation), and Yee, N (13 citation).

**Figure 5.** Most cited authors**Table 3.** Most cited authors

Author	Citations	Total link strength
Graesser, Ac	18	0
Dwivedi, Yk	16	38
Wang, Yt	14	48

Yee, N	13	9
Park, Sm	12	31
Bailenson, Jn	11	6
Lee, Lh	11	25
Duan, Hh	10	35
Github	10	0
Huynh-The, T	10	36

3.4 Most used words in the abstract sections

In order to create a map based on text data for the most used words in the abstracts of articles, the Web of Science bibliographic database file was uploaded into the programme. Then, abstract and binary counting method was selected as field. The minimum number of occurrences of a term was set as 10 and the number of terms to be selected was automatically stated to be 45. The map created from this is given in Fig. 4. It shows three clusters and the word ‘technology’ (f=63) is the most used word found in the abstracts, ‘reality’ (f = 51), ‘student’ (f = 44), agent (f = 37), challenge (f = 36), effect (f = 35), metaverse (f = 35), time (f = 30), information (f = 30). These results indicate that the articles mostly focus on technology, agent, challenge, effect, metaverse, time, and information. When the distribution of these words is shown on a year-by-year basis, it is evident that more recent articles tend to focus on student and metaverse. The distribution of the most used words in article abstract is presented in Table 4 and Figure 6 while the distribution of most used words in articles abstract by year is presented in Figure 7.

Table 4. Most used words in the abstracts

Term	Occurrences	Relevance score
Technology	63	0.5558
Reality	51	0.3406
Student	44	0.6845
Agent	37	0.9082
Challenge	36	0.6718
Effect	35	0.7102
Metaverse	35	1.7587
Information	30	0.4073
Time	30	0.5277
Participant	28	1.6567
Experiment	27	1.5136
Tool	26	0.5242
Issue	24	0.7984

Concept	23	0.7455
Human	22	1.2653
Task	22	0.5464
Video	21	0.6889
Patient	20	1.298
Need	19	0.4783
virtual environment	19	0.388
virtual world	19	1.4142
Year	18	1.0019
Group	17	1.1799
implementation	17	0.3411
Opportunity	17	0.8077
Teacher	17	1.1541
Text	17	0.341
Type	17	0.4166
Interest	16	0.6153
Term	16	0.5698
Training	16	1.7694
Addition	15	0.3902
Advancement	15	0.5685
Limitation	15	0.4929
Problem	15	0.7018
Simulation	15	0.5849
Chatbot	14	2.4894
Effectiveness	14	0.6381
Implication	14	1.8385
Order	14	1.6326
Blockchain	12	2.7882
Internet	12	1.7772
Number	12	2.8032
Individual	10	0.4767
Total	10	1.7385

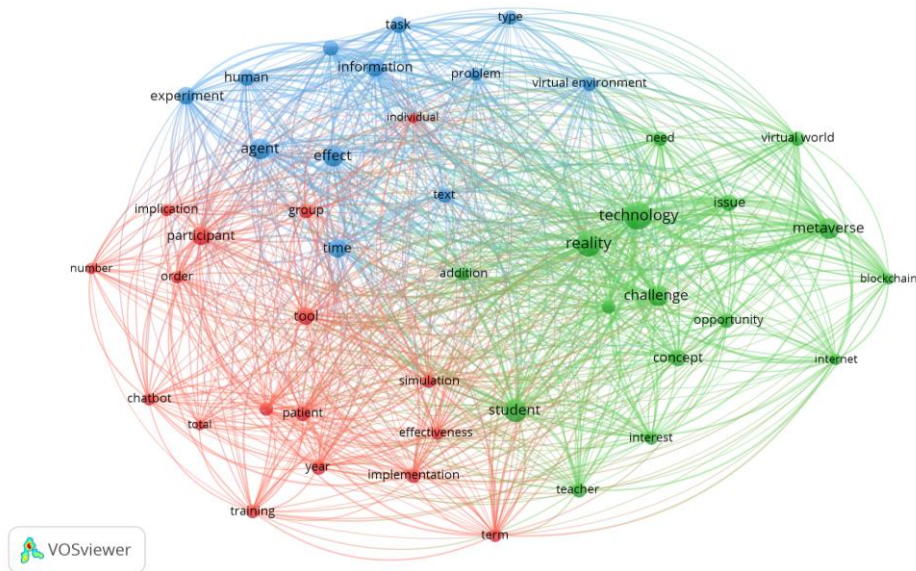


Figure 6. Most used words found in article abstracts

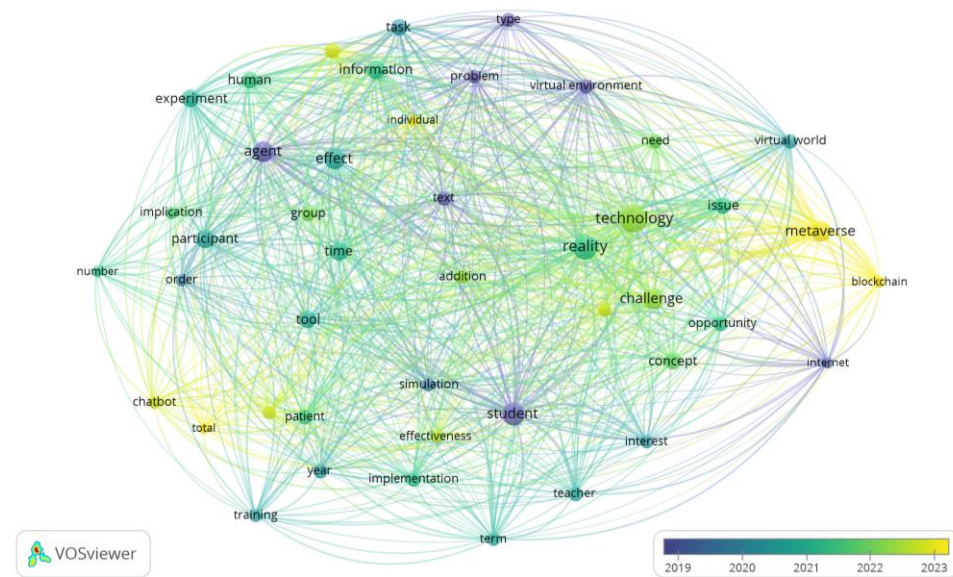


Figure 7. Distribution of most used words in article abstract by year

3.5 Sustainable Development Goal usage in the studies

The data extracted from the web of science shows that SDG 3 ‘good health and well-being’ was found to be used the most in the studies ($f = 38$), SDG 04 ‘quality education’, and SDG 11 ‘sustainable cities and communities’. It is evident

that most of the articles focused on only 6 SDGs out of 17 SDGs as shown below in Table 5.

Table 5. Most Sustainable Development Goal use in the articles

Sustainable Development Goals	Count
SDG: 03 Good Health and Well Being	38
SDG: 04 Quality Education	27
SDG: 11 Sustainable Cities and Communities	8
SDG: 16 Peace and Justice Strong Institutions	3
SDG: 05 Gender Equality	1
SDG: 10 Reduced Inequality	1

4. Discussion

This study was designed with the bibliometric mapping analysis method which aims to analyze literature on the use of artificial intelligence and avatars in education. The studies on the Web of Science database has been examined. According to the findings obtained from VosViewer, Arthur C. Graesser is the most cited author (18 citations).

The results indicate that the most used words in abstracts are technology, reality and student. This finding shows that the studies included in the scope of the research focus on technological aspects on the subject. Moreover, the fact that the word reality is among the most used words indicates that immersive technologies are emphasized in the studies and that technologies such as augmented reality, virtual reality, extended reality are used together with avatars in educational environments. The results of Liarokapis, Milata and Skola's (2024) study indicated that the use of avatars and artificial intelligence technologies with extended reality provides dynamic and engaging learning environments for learners. In parallel with these, the most used words in studies are artificial intelligence, metaverse and avatars.

The finding obtained regarding the usage of Sustainable Development Goals in the studies is also one of the striking findings of the research. Good Health and Well Being SDG has become the most preferred Sustainable Development Goal. The reason for this can be shown as the prevalence of avatars and artificial intelligence applications in health education applications and the fact that research on the well-being and mental health of students can also be carried out using the same technology. Hamilton (2024) argues that the use of these technologies in medical education will make formative simulation more accessible, customizable, realistic, and widespread. The other preferred STG is Quality Education. This finding was not a surprise since the studies within the scope of the research were related to education.

5. Conclusions

In this study, articles in the Web of Science database were scanned with the title “Avatars and Artificial Intelligence in Education” in the scope of bibliometric analysis. The VosViewer software was used in order to obtain data regarding the authors with the highest number of studies, countries where the highest number of studies were conducted regarding the research keywords, the most used words in abstract sections of studies as well as the studies where the most used Sustainable Development Goals are mentioned.

The findings show that based on the research keywords the Professor Arthur C. Graesser at the University of Memphis is the most influential author in the literature. The countries with the highest number of documents in the field of study are the China, USA, Germany and Japan and this finding is also parallel to the number of citations of documents based on the country. As a result, the keywords technology, reality and are the most used in studies. This study aimed to present current research on avatars and artificial intelligence in education and to guide future studies.

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Artificial Intelligence in educational assessment: A bibliometric review of current applications and future perspectives

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Abstract: *This study aimed to examine the studies on the use of artificial intelligence in the educational assessment process using the bibliometric analysis method. Scopus and Web of Science databases were preferred in the study and 733 documents were analyzed. The majority of the documents were published as journal articles and conference papers. In addition, English was preferred in almost all of them. It was determined that the studies on the use of artificial intelligence applications in the Educational Assessment process were carried out in the USA, China and England. The most frequently used keywords in the studies by the researchers were determined as “Artificial Intelligence”, “Students”, “Learning systems”, “human”, “teaching”, “machine learning”, “education”, “humans”.*

Keywords: Educational Assessment, Artificial Intelligence, AI, Formative Assessment.

1. Introduction

Artificial intelligence is a field of science that aims to create systems that can make decisions and perform tasks performed by humans faster and without the need for human intervention (Fetzer, 1990). Artificial intelligence applications can revolutionize many areas, such as disease diagnosis in health, financial forecasts and decision-making in economics, and autonomous vehicles in transportation. Artificial intelligence systems maximize performance by using natural language processing, expert systems, and deep learning algorithms, a machine learning sub-branch.

Big data is analyzed through algorithms, allowing artificial intelligence to recognize patterns and discover insights beyond human cognition. With artificial intelligence applications, ways to access information have changed. Applications

that process big data, identify complex patterns, and offer personalized solutions have become an excellent resource for every individual who learns.

As in many sectors, artificial intelligence applications have been widely used in the education sector for years. In fact, in 2019, the Artificial Intelligence and Education Council Conference was held, where many country ministers, United Nations representatives and academics participated, and decisions were made by discussing the use of artificial intelligence applications in education. At the conference held in Beijing, it was decided that the Sustainable Development Goals should be adhered to, especially the principle of quality education, and that artificial intelligence applications should be respectful of human rights and always human-centered. Accordingly, it was suggested that artificial intelligence applications should be used in a format that supports teachers. It was suggested that regulations should be developed in a way that data will be used transparently and securely (Krotz & Schelhowe, 2020). Artificial intelligence applications that will be developed in accordance with these principles will help learners personalize their learning processes while providing effective and interactive learning environments that will reduce the workload of educators. Despite the many opportunities that artificial intelligence applications provide, concerns about how they can be integrated into education continue (Sbaffi & Zhao, 2022; Gustilo, Ong & Lapinid, 2024). Applications such as ChatGPT have also begun to be used in education because they produce fluent texts (Baskara & Mukarto, 2023; Gustilo, Ong & Lapinid, 2024). Their use for content generation purposes is seen, from planning lesson plans and activities to student evaluation (Khasawneh, Ismail & Hussen, 2024).

In their studies, researchers mention that well-designed assessment processes and tools should be used to determine whether learners have learned a subject. They also note that traditional assessment practices such as multiple-choice tests and short-answer questions are widely used and cause some problems. The most important issue is that the design process is time-consuming (Swiecki et al., 2022). Similarly, common exam stress can distract learners from the learning process, and traditional exam processes are time-consuming for both teachers and learners (Luckin, 2017).

Many researchers mention that using artificial intelligence applications for evaluation purposes in the learning process is one of the most important opportunities (Cope, Kalantzis & Sears, 2021; Swiecki et al., 2022; Hopfenbeck et al., 2023; Zhai & Nehm, 2023). Researchers today indicate that formative assessment motivates students more (Leenknecht et al., 2021; Kültür & Kutlu, 2021). AI applications are designed to partially or completely automate traditional assessment practices. Assessments can be designed with AI applications and even be conducted and scored by the application. Researchers have designed AI-powered assessments to provide teachers, learners, and families with regular feedback on how and how much students are learning and how much they are progressing toward their learning goals (Luckin, 2017).

Researchers have shown that artificial intelligence applications help evaluate the participation of learners in the specified lesson, while also helping to determine successful and relatively weak students in the educational institution according to their levels. Individual curriculums can be designed for the specified groups through artificial intelligence applications to increase students' performance. These applications not only increase learner success; they can also prevent school dropouts by helping to attract more students to the learning process (Dhara et al., 2022).

Many studies have examined the effects of using artificial intelligence applications in formative assessment processes. Researchers support teachers in formative assessment practices such as providing timely feedback to students and designing curriculum according to results (Zhai, He & Krajcik, 2022). In addition to many opportunities, it also causes concerns in the education world. Therefore, this study aims to determine the current research trends in artificial intelligence applications used for formative assessment. For the reasons mentioned above, a bibliometric study was conducted to determine the research topics and important trends in the field. This study, which can be a guide for future research, will help understand the effects of the use of artificial intelligence applications in educational assessment.

2. Methodology

Bibliometric analysis was conducted to systematically evaluate studies investigating the use of artificial intelligence applications in the educational assessment process. Large-volume data sets can be analyzed with bibliometric analysis, which is used in many studies (Ellegaard & Wallin, 2015; Donthu et al., 2021). In the educational assessment process, which researchers conducted the most studies on the use of artificial intelligence applications, which studies received the most citations in the studies on the subject, which countries gave the most importance to the subject, and the most frequently used keywords for determining the conceptual structure were determined.

2.1 Data collection

The data needed for the bibliometric analysis method was obtained from the SCOPUS and Web of Science (WoS) Core Collection databases. SCOPUS and WoS, which are the information and technology providers of the scientific research community, were selected because they are databases containing many high-impact scientific resources, including open-access journals (<https://webofscience.help.clarivate.com/Content/home.htm>, <https://www.elsevier.com/products/scopus>). In the research, the topic option, which searches for article title, abstract, keyword and author keywords in the Web of Science database, and the Article Title and abstract, Keywords in Scopus were preferred, and the keywords ("artificial intelligence" OR "AI") AND ("educational assessment" OR "learning evaluation" OR "academic assessment"

OR "learning assessment" OR "digital assessment" OR "formative assessment") were searched. All years, languages and all document types were included in the search. The query on Scopus yielded 633 publications, and the query on WoS yielded 261 publications. The data collection process ended on December 28, 2024. Publications indexed in both databases were identified and duplicates were deleted. As a result, the study was conducted with 733 publications.

2.2 Data analysis

In this study, VOSviewer software, which has multidimensional analysis, datasets, mapping and visualization features, was used (VOSviewer, 2020). VOSviewer is used as a free software and can easily create bibliometric maps consisting of big data (van Eck & Waltman, 2010; VOSviewer, 2020). The distribution of the publications included in the study according to publication years, countries, document types, and languages was calculated using percentage values.

2.3 Limitations of the study

In terms of method, the study was limited to the bibliometric analysis method and the data were analyzed with citation and co-occurrence analysis techniques. The search index of the research was limited to the keywords "Artificial Intelligence, AI, educational assessment, learning evaluation, academic assessment, learning assessment, digital assessment, formative assessment". Another limitation of the study is that only Scopus and WoS databases were used.

3. Findings

3.1 Distribution of studies according to publication years

The findings obtained from the analysis showed that 733 documents were in the databases examined "regarding the use of artificial intelligence in the educational assessment process" between 1996 and 2025. Figure 1 presents the distribution of the documents by year.

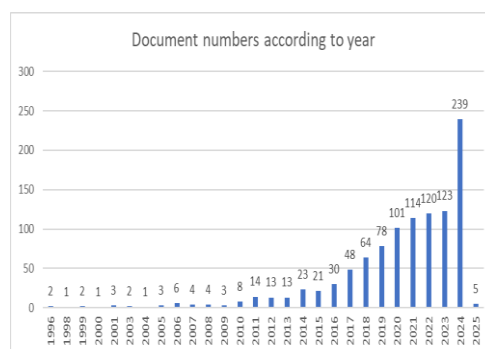


Figure 1. Publications over years

As seen in Figure 1, the first studies on using artificial intelligence applications in the educational assessment process were published in 1996 (n=2). The years when intensive research on the subject started were after 2016 (n=30). The most studies on the subject were in 2024 (n=239). This finding shows us that this subject is a trending research topic today.

3.2 Distribution of research according to document types

Table 1 presents the numbers and percentages of studies conducted on the use of artificial intelligence applications in the educational assessment process in the WoS and Scopus databases according to document types.

Table 1. Frequency and percentages of documents

Document Type	Frequency	Percentage
Articles	365	49.80
Conference paper	306	41.75
Book Chapter	58	7.91
Book	4	0.55

As seen in Table 1, 49.80 % of the research on using artificial intelligence in the educational assessment process was published as a journal article. The subject was also included 41.75 % as a conference paper.

3.2 Distribution of research according to the languages of the document

When the languages in which the documents were published are examined, almost all (98.80%) were published in English, as seen in Table 2.

Table 2 Distribution of documents according to languages

Document Language	Frequency	Percentage
English	722	98.8
Spanish	5	0.75
Persian	1	0.15
German	1	0.15
Chinese	1	0.15

3.3 Co-occurrence of all keywords

In the studies conducted on the use of artificial intelligence applications in the educational assessment process, a co-occurrence analysis was performed to determine the most frequently used keywords. In order to determine the trend keywords related to the subject, a minimum number of co-occurrence of a keyword was determined as 5. For each of the 169 keywords repeated 5 times among 3834 keywords, the total link strength found with other keywords was

calculated. The keywords with the largest total link strength were selected and a visual was created. The strongest expressions in terms of total link strength were determined as “artificial intelligence”, “students”, and “learning systems” as a result of the analyses performed with 169 observation units that were seen at least five times and had relationships, a total of 5 clusters, 3651 links and 9397 total link strengths were determined.

Table 3 Most popular keywords and total link strength

Keyword	Occurrences	Total Link Strength
Artificial intelligence	287	1749
Students	121	867
Learning systems	92	645
Human	52	577
Teaching	70	522
Machine learning	67	502
Education	63	486
Humans	37	437
E-learning	62	431
Formative assessment	82	411

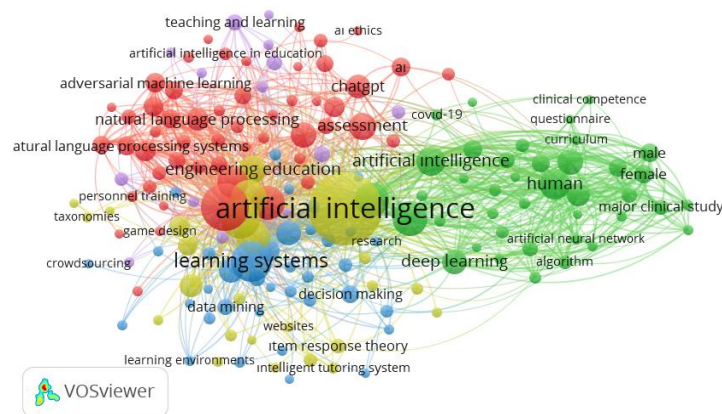


Figure 2. Most used keywords

As seen in Figure 2, 5 different clusters were formed in the mapping of the research conducted on the use of artificial intelligence applications in the educational assessment process. It shows that the subject of “Artificial Intelligence” is the main theme. As seen in the green cluster, human-centered assessment themes are taken as the basis in the research conducted on the use of

artificial intelligence in educational assessment processes. Another striking point in the visual is that although the keyword “Generative Artificial Intelligence” is not repeated as much as the others, the total link strength is 57. This finding shows us that these generative AI technologies are a rising research area in the educational assessment process.

3.4 The most cited articles about educational assessments with AI

The citations to publications show us how much other researchers benefit from that publication. In short, we can say that publications with high citation numbers lead the field. Citation-document analysis was performed with 203 publications that received at least 5 citations in the network mapping analysis. Only 13 documents meet the thresholds. This finding shows us that the studies in this field are not carried out with much collaboration. Figure 3 shows the network visualization between 13 documents. 6 clusters and 18 connections were determined in the mapping.

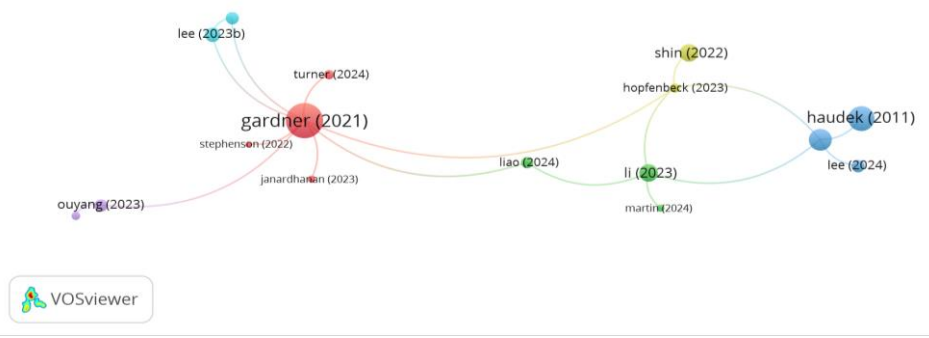


Figure 3 Most cited authors

The 6 most cited studies in the research conducted on the use of artificial intelligence applications in the educational assessment process are presented in the table.

Table 4. The most cited articles

Rank	References	Citation
1	“Kooli, C. (2023). Chatbots in education and research: A critical examination of ethical implications and solutions. <i>Sustainability</i> , 15(7), 5614”	216
2	“González-Calatayud, V., Prendes-Espinosa, P. & Roig-Vila, R. (2021). Artificial intelligence for student assessment: A systematic review. <i>Applied Sciences (Switzerland)</i> , 11(12), 5467.”	153
3	“Gardner, J., O’Leary, M., & Yuan, L. (2021). Artificial intelligence in educational assessment: ‘Breakthrough? Or buncombe and ballyhoo?’. <i>Journal of Computer Assisted</i>	90

- Learning, 37(5), 1207-1216”
- 4 “Elbanna, S., & Armstrong, L. (2024). Exploring the 79
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- 5 “Haudek, K. C., Kaplan, J. J., Knight, J., Long, T., Merrill, 46
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technology to improve formative assessment of student
conceptions in STEM: forging a national network. CBE—
Life Sciences Education, 10(2), 149-155.”
- 6 “Zhai, X., & Nehm, R. H. (2023). AI and formative 33
assessment: The train has left the station. Journal of
Research in Science Teaching, 60(6), 1390-1398.”

When the most cited studies are examined, it is seen that the study titled “Chatbots in education and research: A critical examination of ethical implications and solutions.” is in the first place with 216 citations. This study focuses on the ethical problems that will arise from the use of artificial intelligence applications in the evaluation process. This study, which attracted the attention of researchers, was published in the journal Sustainability.

3.5 The most productive countries

In the educational assessment process, a citation-countries analysis was conducted to determine the most productive countries for the use of artificial intelligence applications. When mapping the data, it was determined as a criterion that countries should have at least 5 publications and 15 citations. Although 33 countries met these criteria, 16 countries with links were determined in the mapping. According to this finding, the country mapping according to the number of publications and citations is presented in Figure 4.

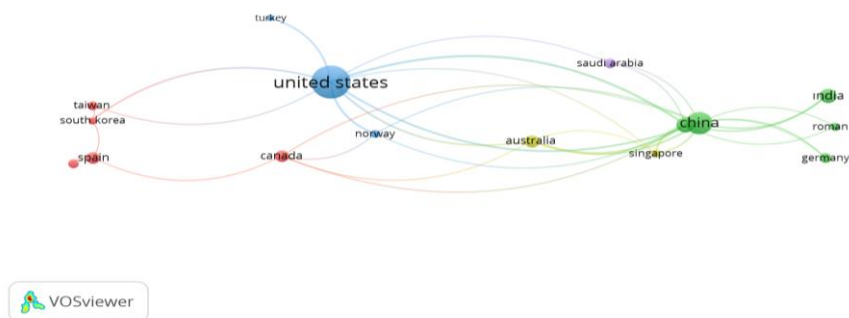


Figure 4. Documents by countries

5 clusters, 33 links and 57 total link strengths were determined. The country with the most citations and publications was determined as US (179 articles, 2132 citations). Then China (85 articles, 484 citations), United Kingdom

(40 articles, 509 citations), Australia (26 articles, 369 citations). The top three countries in terms of total link strength are United Kingdom (22), United State (20) and China (19).

4. Discussion and conclusions

This study aims to examine 762 published studies on the use of artificial intelligence applications in the educational assessment process scanned in the Web of Science and Scopus databases. Since thirty-two documents in the dataset were scanned in both databases, duplicates were deleted and the analyses were performed with 763 documents. While scanning the Web of Science, the keywords “artificial intelligence”, “AI”, “educational assessment”, “learning evaluation”, “academic assessment”, learning assessment”, “digital assessment” and “formative assessment” were preferred in the Subject field and while scanning Scopus, the keywords “artificial intelligence”, “AI”, “educational assessment”, “learning evaluation”, “academic assessment”, learning assessment”, “digital assessment” and “formative assessment” were searched with appropriate conjunctions. The first studies on the use of artificial intelligence applications in the educational assessment process were carried out in 1996. Since 2013, the number of studies has started to increase every year. The increase in deep learning and machine learning algorithms after 2010 may have encouraged their use in education.

According to the results obtained from the analyses carried out in order to determine trending topics in research on the use of artificial intelligence applications in the educational assessment process; The topics of “formative assessment”, “machine learning”, “e-learning”, “learning systems”, “human”, “chatgpt”, and “higher education” have been intensively researched. The increasing use of online learning environments, especially after COVID-19, has caused changes in evaluation processes in education.

When the most cited publications were examined, it was determined that all six publications were journal articles. This result shows us that peer-reviewed journals scanned in WOS and Scopus increase visibility and contribute to science.

When we look at the distribution of publications by country, it was revealed that the publishers were the US, the UK, and China; almost all of the documents were published in English. In the future, researchers conducting research on the use of artificial intelligence in the educational assessment process can plan their research by considering the results obtained from this study. In particular, researchers can understand which studies on the subject should be read first from this study.

The limitation of the study is that the analyses were conducted only on publications obtained from keywords in the WoS and Scopus databases. In future studies, studies can be conducted in internationally respected databases such as IEEE and Ebsco. In addition, according to the results of this study, systematic

analysis can be performed to obtain more detailed information in future studies on the use of artificial intelligence applications in the educational assessment process.

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Recurring learning activity planning model

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Abstract: *The paper proposes a model for recurrent planning of learning activities from an academic course or school lessons. This model can be adapted for other types of learning activities. Databases and text/pdf files were used to store the information used. The model uses two main components, one for configuring learning activities: calendar dates, time of occurrence, online connection links, necessary auxiliary materials and a second component for generating the interface of a particular learning activity: course, laboratory, seminar, lesson. Modern web programming technologies were used to implement this model.*

Keywords: learning, webpage, modelling, database, interface.

1. Introduction

Nowadays, teachers prepare their courses in detail to make their teaching work easier and to facilitate easier and more assisted learning for students. Thus, in the academic environment, the teacher and students must have the working and presentation materials at hand – in a format that is as predictable and attractive as possible. This activity is presented in (Early Education Nation, 2024) and (Homeschool Solutions, 2024). The schedule of learning activities is repetitive week after week and for this reason recurrent planning is a mechanism often used by teachers. At the beginning of the course period, the teacher prepares his/her activities and teaching materials and may have his/her own style of planning, different from those proposed by existing e-learning platforms such as MOODLE or GOOGLE CLASSROOM, aspects presented in (Hamidi et al., 2011) and (Popescu et al., 2020). Also, similar approaches for scheduling are presented in (Bradley, 2021) and (Semana et al., 2018) or testing in (Popescu et al., 2016) and (Popescu et al., 2023).

The model that we will present in this paper uses databases to store information and web pages for the learning activity interfaces. For entering data into databases, secure connection, setting activity data, generating connection links for communication and creating work interfaces we will use scripts – in this way the model can be implemented through an easy-to-manage web application.

The paper is fragmented into sections for a modular and fluent presentation, to quickly understand the ideas of the model and the implementation method. In the

final part of the paper, the features of the model and what activities can be integrated to extend the model and make it more efficient are presented.

2. Model presentation

The recurring learning activity planning model has two main components:

- ReConfig (Recurring configurator),
- UIGen (User Interface Generator)

ReConfig takes the course-related data from the professor and enters it into a database. Among the data taken from the professor are the day and time of the week in which the learning activity will take place, the materials (files, images, presentations, etc.) usable in all courses.

UIGen generates recurring activities for all weeks between certain time limits taken from the professor along with other restrictions. Also in this component, the materials specific to each week of the course (online connection links, files specific to certain courses, specific topics, etc.) are entered, as well as configurations of the interface specific to each week, if applicable.

Figure 1 shows the diagram of the recurring planning model that contains the two components presented previously.

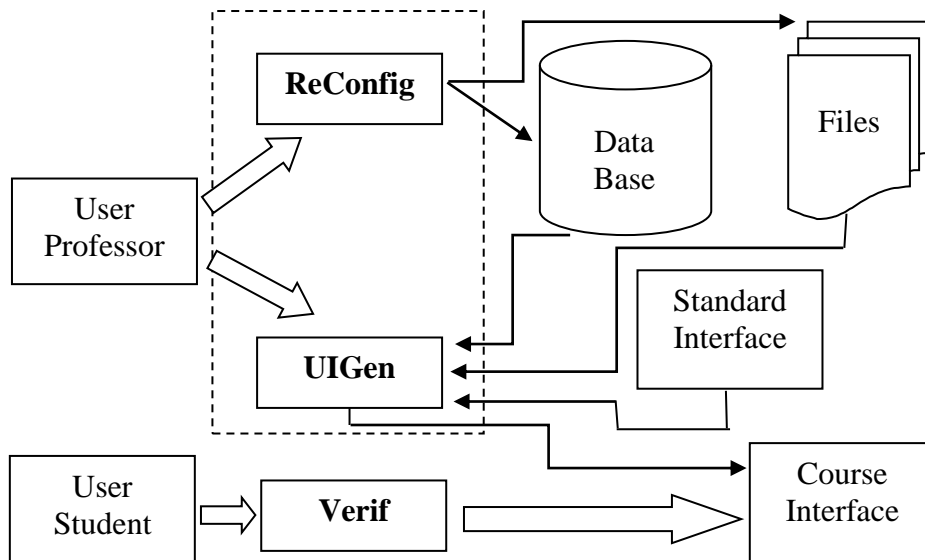


Figure 1. Recurring Learning Activity Planning Model

For access to the ReConfig and UIGen components, access is only for the professor, and for students, access is verified using the Verify component. Students only have access to the course interface which is generated recurrently by UIGen

using a Standard Interface and populated with course-specific data. The Standard Interface comprises the presentation of the scheduled activities to all users (e.g., teachers, students) and it is generated based on the database information.

The model presented in the previous paragraphs can be mathematically modelled based on a set of activities that have specific characteristics and must be programmed in a defined time interval. Let there be a set of learning activities:

$$A = \{a_1, a_2, \dots, a_n\}$$

Each activity a_i is characterized by:

- predefined scheduling (S_i):

$$S_i = \{(d_{i,1}, t_{i,1}, l_{i,1}), (d_{i,2}, t_{i,2}, l_{i,2}), \dots, (d_{i,k}, t_{i,k}, l_{i,k})\}$$

where $d_{i,j}$ is the day scheduled for the activity a_i for the j^{th} repetition, $t_{i,j}$ is the starting hour and $l_{i,j}$ is the duration of the activity;

- recurrence frequency $f_i \in \mathbb{N}$ is a number of time interval (e.g, an activity a_i is repeating after 1 week, thus $f_i = 1$);
- files and resources

$$R_i = \{r_{i,1}, r_{i,2}, \dots, r_{i,m}\}$$

A scheduling interval T is set for the activities, $T = [TS, TE]$, where TS is the start time and TE is the end time for the period desired to generate the activities. In this matter, each activity a_i with $(d_{i,j}, t_{i,j}, l_{i,j}) \in S_i$ must respect the condition:

$$TS \leq d_{i,j} \leq TE, \forall i \in \{1, \dots, n\}, \forall (d_{i,j}, t_{i,j}, l_{i,j}) \in S_i$$

For each activity a_i with $(d_{i,j}, t_{i,j}, l_{i,j}) \in S_i$, with k recurrences, each recurring instance is determined by the frequency f_i :

$$(d_{i,j}, t_{i,j}, l_{i,j}) = (d_{i,0} + k \times f_i, t_{i,0}, l_{i,0}), j \in \{0, 1, \dots, k\}$$

To ensure that activities do not overlap on the same day, it is necessary to:

$$(t_{a,j} + l_{a,j} \leq t_{b,j'}) \vee (t_{b,j'} + l_{b,j'} \leq t_{a,j}), \forall a \neq b, \forall j, j' \text{ such } d_{a,j} = d_{b,j'}$$

This constraint guarantees that, for any two activities scheduled on the same day, the time slots do not overlap.

This mathematical model provides a clear structure for planning recurring activities, integrating the elements of predefined schedules, frequency, resources, and scheduling period. It serves as a theoretical basis for developing an application to automatically manage schedules and resources needed in the educational environment.

The current implementation may serve as a base for developing a generator of a schedule of recurring activities where the activities have not a fixed date and

time of progress. In this matter, the model would take into account a list of activities, their duration, the frequency and the start and end time interval in weeks (e.g., Week 1, Week 2 etc.). Thus, the problem of the schedule generation transforms into an optimisational one, taking into account a minimum number of overlapping activities that form a list. The model would comprise the next elements:

- the start (TS) and end (TE) times of a time interval desired for the scheduling problem, stated as weeks (e.g., Week 1 with TS = 1, Week 14 with TE = 14);
- the list of activities:

$$A = \{a_1, a_2, \dots, a_n\}$$
- the fixed duration of an activity $l_i \in \mathbb{R}^+$;
- the frequency of the activity $f_i \in \mathbb{N}$, a number of time interval (e.g, an activity a_i is repeating after 1 week, thus $f_i = 1$);
- the number of instances of the activity n_i , computed as the report between the difference between TS and TE and the frequency of the activity f_i ;
- the hourly starting point in time of each activity H_i ;
- the day of week of each activity $D_i \in \{1, 2, \dots, 7\}$, representing the weekdays.

Then, for each week S_j , $j \in \{TS, \dots, TE\}$, the total number of overlapping is computed:

$$C(S_k) = \sum_{i,j \in S_k, i \neq j} o_{i,j}, o_{i,j} = \begin{cases} 1, & \text{if } (D_i = D_j) \wedge (H_i < H_j + l_j) \wedge (H_j < H_i + l_i) \\ 0, & \text{otherwise} \end{cases}$$

Then, using a Greedy strategy, the week with the most overlaps (maximum of $C(S_k)$) is selected. For this week, an optimisational algorithm may be used. For example, for a genetic algorithm, a chromosome is presented as the list of activities in the week k :

$$X = [(D_1, H_1, l_1), \dots, (D_n, H_n, l_n)]$$

The objective function would follow the minimisation of the overlapping of the activities represented as triplets in the week k , which would be the minimisation of the function $C(S_k)$. Then, a genetic algorithm would be applied in order to minimise the value of the function C .

The implementation of this model optimizes activity scheduling by reducing overlaps and accelerating computation, as the genetic algorithm only acts on the most problematic week. Greedy selection prioritizes conflicts, and crossover and

mutation allow for rapid adjustments. The model is scalable, flexible, and easy to extend with additional constraints, such as room or teacher allocation.

Overall, extending the initial model with a genetic algorithm allows for optimizing the distribution of scheduled activities, reducing overlaps and maximizing planning efficiency. The algorithm can adjust the allocation of resources (rooms, teachers) and balance the timetable load, avoiding inefficient scheduling.

3. Implementation

The recurrent learning activity planning model presented in the previous section was implemented using the following web technologies:

- Laravel 11 (PHP) - was used to develop the backend component, providing a scalable and robust base to manage the logic part of the application, the interaction with the database, as well as ensuring secure communication between the server and the client;
- Vue.js 3 - was used to develop the frontend component, providing a flexible and reactive framework to create dynamic and user-friendly interfaces. Its component-based structure ensures modularity of the user interface but also easier maintainability;
- Mysql 8 - the relational database that was used to store the application data. Due to its advanced functionalities, such as JSON support, but also the improved indexes mechanisms, it allowed the creation of efficient queries for scheduling activities.

Laravel 11 was mainly used for:

- providing API endpoints for the frontend
- interacting with the database to store and retrieve information efficiently
- managing activities by implementing their storage logic

Vue.js was mainly used for:

- designing an interactive interface for users, where they can create, edit, and view recurring learning activities
- implementing real-time validations of activities
- using Vuex for state management to ensure a seamless experience

Figure 2 shows the interface for the activities calendar. As we can see in the calendar, on a given day, the group of students who are going to have the lesson at the mentioned start time is marked. We have several colors present, these represent:

- green for a lesson that will take place online
- gray for a lesson that will take place physically (offline)
- red-gray represents a lesson that has been canceled (for example, for the image, 3 lessons were scheduled for that group but the one on January 3rd could not be held, so it is marked as canceled).

In Figure 2 we have the weekly version of the calendar where we can see in more detail how long each lesson lasts (the block associated with the lesson stretching over the duration range).

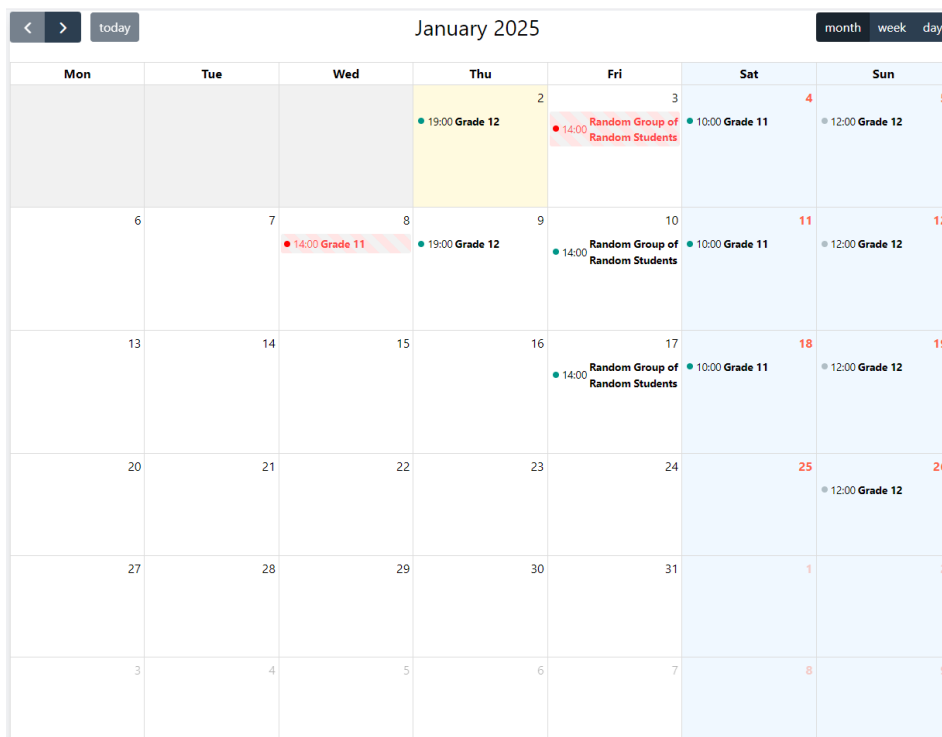


Figure 2. Recurring Learning Activities Calendar (monthly view)

To achieve these things in the interface, the Fullcalendar component from Vue.js was used.

Figure 3 shows the interface for the form for adding an activity. The fields in the form represent:

- group - the group for which the activity is planned
- day of the week - the day of the week it will take place (1 for Monday, 2 for Tuesday, etc.)
- start and end time - the interval in which it will take place

- start date - the date it will start
- occurrences - the number of weeks in which it will take place (for example 4 to have each week for a month), and the end date (end date) will be automatically filled in based on the chosen value
- online lesson - a simple checkbox to determine whether the activity is online or not

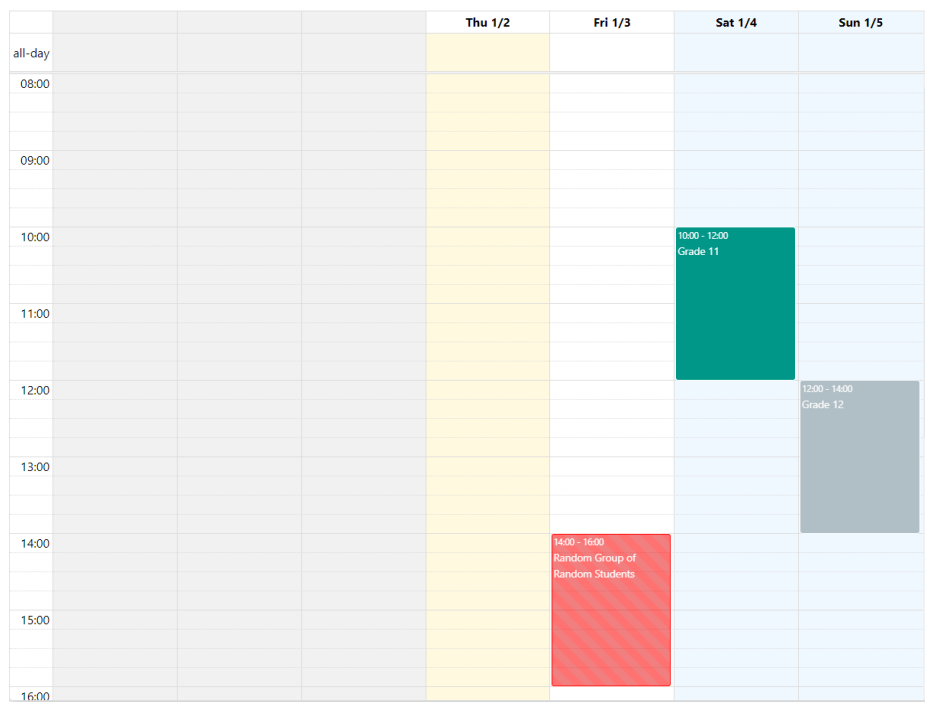


Figure 3. Recurring Learning Activities Calendar (weekly view)

Once completed, the form in figure 4 is first checked by the interface (the end time should not be before the start time as well as other validations), then this data is sent to the backend via a request. Once they arrive here, they are checked again much more strictly (there are validations to avoid overlapping activities, for example), and then if everything is considered in order, they are stored in the database.

The image shows a web form titled "Add Lesson" with a close button (X) in the top right corner. The form contains the following fields and controls:

- Group:** A dropdown menu with the text "Select a group" and a downward arrow.
- Day of the Week:** A text input field containing the number "4".
- Start Time:** A time selection field with "HH:mm" placeholder text.
- End Time:** A time selection field with "HH:mm" placeholder text.
- Start Date:** A date selection field showing "01/16/2025" and a calendar icon.
- Occurrences:** A text input field with the placeholder "Enter number of occurrence".
- End Date:** A date selection field with the placeholder "mm/dd/yyyy".
- Online Lesson:** A checkbox that is currently unchecked.
- Save:** A green button with a white checkmark and the text "Save".

Figure 4. Recurring Learning Activities Calendar (activity add form)

4. Conclusions and future work

The Recurring Learning Activity Planning model contains the mechanisms necessary to plan a series of activities using various information resources in a simple and intuitive presentation. This model can be integrated into e-learning tools and platforms at the institutional level, allowing the use of specific configurations. In the coming period, we want to use the model in a complex teaching - learning - assessment application, such as those presented the mentioned research papers, and to develop it to show its efficiency. At the same time, recurring tasks and assignments for students can be planned or testing methods can be used, like in those specified in the mentioned similar works. Also, the implementation of an additional feature of an alternative scheduling configuration using genetic

algorithm may lead to improvements. Extending the original model with a genetic algorithm allows for the optimization of activity scheduling, modifying hours and days to minimize overlaps and create a more balanced schedule. By applying selection, mutation, and crossover, the algorithm can find more efficient distributions of activities, respecting the imposed constraints and maximizing the use of available time.

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Multidisciplinary approach based on the application of interdisciplinary connections in teaching natural sciences in lower secondary education stage

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Abstract: *This work describes a conducted pedagogical study aiming to find the benefit from the application of inter- and intradisciplinary connections in the field of information technologies-natural sciences during the training of students in lower secondary education stage. The role of the inter- and intradisciplinary connections in the education of natural sciences by the use of information technologies is discussed. The analysis of the results obtained from the applied training with the chosen methodology in 5th, 6th and 7th grade of a middle school is presented. The working hypothesis stating that the application of inter- and intradisciplinary connections in the corresponding field enhances the quality of the study process and the efficiency of the students’ training in lower secondary education stage was confirmed.*

Keywords: natural sciences education, information technologies, inter- and intradisciplinary connections.

1. Introduction

The interdisciplinary connections in education play a key role in the multidirectional and overall development of students. They can be used as a tool for activating the students’ cognitive ability. The establishment of the efficiency of such relationships in the training in natural sciences in lower secondary education stage and their interaction with the information technologies (IT) represent a challenge that needs a special attention. The conducted experimental training in natural sciences in 5th, 6th and 7th grade (general education preparation, interest activities), based on a methodology including interdisciplinary connections in the field of information technologies – natural sciences, aimed to find if the efficiency of students’ education in lower secondary education stage could be enhanced in this direction.

The interdisciplinary connections can be realized by:

- integration of topics from different subjects in one lesson or project, where students can apply the acquired knowledge and skills in them.

- organization of intersubjective modules, where students can study specific topics as they use their knowledge acquired from several subjects.
- creation of intersubjective projects or studies, where students can work in a team and apply their knowledge acquired from different subjects in order to solve real problems.

The use of such connections leads to a number of benefits for students:

- enhances their motivation (Stoitsov & Stoitsova, 2019) and engagement, as there is the possibility for them to participate in integrated and interesting projects which are significant and have practical applications;
- develops their social skills and work in a team, as students can work together and use their different skills and knowledge to solve tasks.
- more efficient application of knowledge and skills in real world, as students have the possibility to study topics from different sciences, which are connected to each other and have applications in real life.
- development of creativity and innovation skills, as students can use different knowledge and skills to create new ideas and solutions to problems.

1.1 Research aim and research questions

In the pedagogical dictionary, interdisciplinary connections are interpreted as the mutual coordination of educational programs, determined by the system of science and didactic goals. There are numerous publications related to the justification of this concept: (Velcheva, 2024), (Velcheva, Dimitrov & Shopova, 2023), (Mollov & Stoitsov, 2020), (Mollov, 2019), (Stoitsov & Stoitsova, 2019), (Chipangura & Aldridge, 2017), (Dori & Barak, 2001). The conclusion drawn from all of them is that interdisciplinary connections assist the creation of a more comprehensive and interdisciplinary educational program that reflects the real needs of students. This leads to greater student engagement in the learning process by allowing them to study topics related to their interests and with real-life applications.

The main aim of the current study is the approbation and processing of the results obtained from the applied multidisciplinary educational approach based on an interdisciplinary methodological model for teaching natural sciences in the 5th, 6th and 7th grades of the lower secondary school which aims to increase the efficiency of educational activities through the use of interdisciplinary connections between IT and natural sciences.

The main question is whether the applied multidisciplinary educational approach could lead to an enhancement in the quality of the education process as well as in the efficiency of the students' training?

Hypothesis of the Study:

The education in natural sciences in 5th, 6th and 7th grades (extracurricular activities, interest-based classes), which is based on the use of interdisciplinary connections between information technologies and natural sciences, would lead to an improvement in the quality of the educational process and the efficiency of the education of students in the lower secondary education stage.

2. Research methodology

The pedagogical research was carried out during the 2019/2020, 2020/2021, and 2021/2022 school years according to the active regulation of Ministry of Education. This gives a reason to claim that the applied multidisciplinary approach and instruments are modern in the conditions of the active regulations.

The inclusion of IT in educational programs leads to more modern, up-to-date and practical education that meets the needs and interests of contemporary students (Velcheva & Peykova, 2024), (Radev & Vazova, 2023), (Stoitsov & Stoitsova, 2019).

2.1 Sample

The following representative samples were selected for the study:

- 100 students from 5th grade divided in 2 groups consisted of 50 students – experimental (exp.) and reference (ref.) group;
- 100 students from 6th grade divided in 2 groups consisted of 50 students – experimental (exp.) and reference (ref.) group;
- 100 students from 7th grade divided in 2 groups consisted of 50 students – experimental (exp.) and reference (ref.).

A total of 300 students from the middle school in Plovdiv, Bulgaria, participate in the study. The check on the knowledge and skills was made by using tests, covering the study content:

- „Human and nature“ for students from 5th and 6th grade
- „Chemistry and environment protection” for students from 7th grade

2.2 Instrument and procedures

For the aims of the conducted experimental training with the interdisciplinary connections in the field of the information technologies, students used the following tools:

- Project “With a look to the stars” – graphics editors Paint 3D, GIMP and innovative educational applications for virtual and augmented reality Mozaik 3D (Shopova & Dimitrov, 2021), Smart Classroom AR, text

editor Google Docs.

- Project “Green zone”, Project “Air pollution” – text editor Google Docs, editor of electronic tables Google Sheets, applications for content presentation Google Slides, Canva, Slidesgo (Shopova & Garov, 2022).
- Project “Healthy eating” - applications for content presentation Google Slides, PowerPoint, Canva, Slidesgo, text editor Google Docs.
- Project „Plovdiv Hills – the city symbol” – websites and educational applications Canva, LearningApps, Slidesgo, Wordwall, Word Mind, Popplet, virtual and augmented reality Mozaik 3D.
- Project “Structural formulas – a challenge for the 7th grader” – work with Internet and innovative software applications for VR and AR reality Google Arts & Culture, Mozaik 3D, Augment Education, applicable software ACD/ChemSketch.
- Project “Water – a source of life” - Canva, LearningApps, Slidesgo, Wordwall, Google tables, presentations and documents (Shopova, 2021).

The traditional structure of conducting the pedagogical experiment (three stages) was kept:

1. Preliminary experiments;
 - 1.1. Determining the criteria and indicators for the assessment of the results from the tests;
 - 1.2. Developing preliminary tests and tasks;
 - 1.3. Developing a model for quantitative analysis of empirical data;
 - 1.4. Selecting a representative sample and groups;
2. Intermediate control experiment
 - 2.1. Training in the suggested methodology and study content;
 - 2.2. Conducting a test and control exercises;
3. Final experiment
 - 3.1. Analysis of test quality;
 - 3.2. Analysis and presentation of the obtained results;
 - 3.3. Formation of conclusions and assumptions.

The preliminary experiment aimed to provide an information for the preliminary level of the students on previously studied content (Bizhkov & Kraevski, 2002). During the training in the suggested methodology, an intermediate control was applied to check the results from the application of the suggested methodology. The final test was conducted in the end of the studied period.

The developed model (Shopova & Dimitrov, 2023) related to the implementation of interdisciplinary connections between natural sciences and

information technologies represents an organized and relatively stable configuration of the individual elements of the educational process:

- Idea for creating interdisciplinary connections;
- Design of teaching units;
- Development of educational content;
- Creation of teaching materials;
- Teaching in a new way;
- Organization of teaching time;
- Assessment and measurement of achievements;
- Analysis and results of the applied innovation.

3. Data analysis

The criteria and indicators for assessment of the results were selected according to the study program of the following subjects – “Human and nature” for students from 5th and 6th grade and “Chemistry and environment protection” for students from 7th grade. Such criteria and indicators were developed for the preliminary experiment as well as for the final tests for each grade. In this article, we will present only the criteria and indicators for the subject “Human and nature” in 5th grade.

3.1 „Human and nature“ 5th grade, preliminary experiment

1. **Criterion 1** – Knowledge and skills, associated with bodies and matter
 - 1.1. Compare matter, used in the casual life, according to their properties – the ability to burn, to be attracted by a magnet, to conduct heat, to be solved in water, to float or sink (heavier or lighter than water);
 - 1.2. Give examples for the use of matter;
 - 1.3. To list the pollutants of air, water and soil and the approaches for their protection;
2. **Criterion 2** – Knowledge and skills, associated with movement and energy
 - 2.1. Illustrate with examples how the forces (muscular force, gravitation, friction) influence the movement and body shape;
 - 2.2. To list the different types of energy, movement energy, heat energy, solar energy, fuel and food energy;
3. **Criterion 3** – Knowledge and skills, associated with the planet Earth

- 3.1. Link the change of the day with the night with the rotation of Earth around its axis;
- 3.2. Describe Sun as a star (source of light energy);
- 3.3. List the planets from the Solar system;
4. **Criterion 4** – Knowledge and skills, associated with vital processes
- 4.1. Describe the synthesis of nutrients in plants;
- 4.2. Explain the meaning of the plants for the air enrichment with oxygen and the removal of the carbon dioxide in air;
- 4.3. Explain from where the organisms receive energy and how they use it;
- 4.4. Give examples for animals breathing with lungs or gill;
5. **Criterion 5** – Knowledge and skills, associated with organisms and their living environment
- 5.1. Group the animals by their type – insects, fishes, amphibians, reptiles, birds and mammals;
- 5.2. Name the anthropogenic activities, leading to perturbation in the nature equilibrium as well as in the measures associated with its protection.
6. **Criterion 6** – Knowledge and skills, associated with human and his healthy way of life;
- 6.1. List the main nutrients that are necessary for the human organism and the foods that contain them;
- 6.2. Point the causes of contagious illnesses (microbes, bacteria, viruses) and tools for prevention and treating (personal hygiene, vaccines, medicines);
- 6.3. Explain the harmful influence of nicotine, alcohol and drugs.

3.2 „Human and nature“ 5th grade final test

1. **Criterion 1** - Knowledge and skills, associated with bodies and matter
- 1.1. Give examples for diffusion and its meaning;
- 1.2. Measure the volume and mass of solids and liquids;
2. **Criterion 2** – Knowledge and skills, associated with heating
- 2.1. Describe the heating of solids;
3. **Criterion 3** – Knowledge and skills, associated with Earth and Outer space
- 3.1. Explain the change in the seasons, Moon’s phases, the lunar and solar eclipses with the movement of the Earth and Moon;
- 3.2. Compare the planets from the Earth’s group and gas giants according to specific features;

4. **Criterion 4** – Knowledge and skills, associated with matter and mixtures of matter.
 - 4.1. Describe the matter by its content and physical properties;
 - 4.2. Describe two- or multicomponent mixtures;
 - 4.3. Properties of matter and mixtures of matter;
 - 4.4. Application of matter and mixtures;
 - 4.5. Differentiate matter and mixtures according to models;
5. **Criterion 5** – Knowledge and skills, associated with the air
 - 5.1. Describe the air as a multicomponent mixture;
 - 5.2. Point sources of atmosphere pollution – natural phenomena and anthropogenic activities;
 - 5.3. Present different approaches for keeping the air freshness;
6. **Criterion 6** – Knowledge and skills, associated with water and aqueous solutions
 - 6.1. Give examples for matter – water pollutants and their influence on the environment and human’s health;
7. **Criterion 7** – Knowledge and skills, associated with the cell structure of organisms;
 - 7.1. Define cell as a term;
 - 7.2. List, point and index the cells and their parts (cell membrane, cytoplasm, DNA) on an image;
8. **Criterion 8** – Knowledge and skills, associated with vital processes in multicellular organisms;
 - 8.1. Name the matter, necessary for feeding of plants and animals;
 - 8.2. Determine the organs of the breathing system according to their function;
9. **Criterion 9** – Knowledge and skills, associated with the human vital processes;
 - 9.1. List, point (on an image, model) and describe the organs and functions of the digestive system;
10. **Criterion 10** – Knowledge and skills, associated with human – a part of the nature;
 - 10.1. Determine human as a part of the nature.

4. Research results

4.1 Preliminary level

The preliminary level of the students was assessed with preliminary tests in the corresponding subjects – “Human and nature” for the students from 5th and 6th

grade and “Chemistry and environment protection” for the students from 7th grade, included in the experimental study.

The histograms for each of the samples are presented on the following figures: 5th grade preliminary test.

The histograms on Figure. 1 are accompanied by the curve of normal distribution for each group with the corresponding parameters – mean and standard deviation. By using SPSS, a test of normality was done for the empirical results to determine the type of method used for a comparison – parametric or non-parametric.

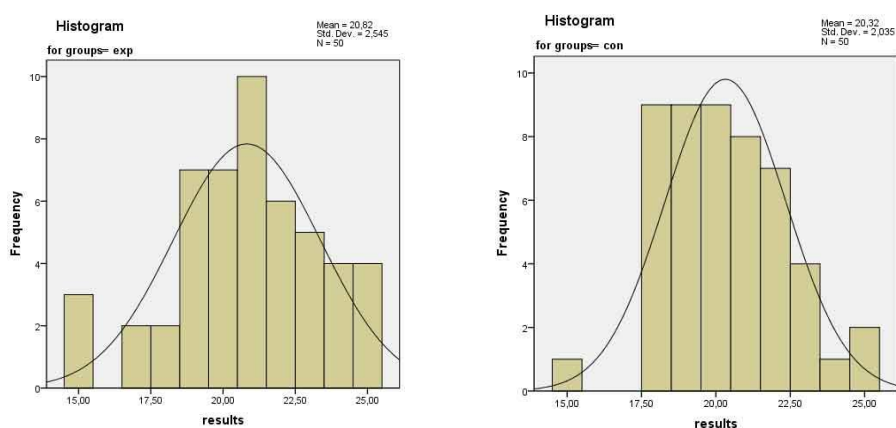


Figure 1. Histograms of the experimental and reference group for preliminary test 5th grade

The software presents the results in two variants shown in Table 1. The value of Sig. for the both tests (Kolmogorov-Smirnov, Shapiro-Wilk) of the two samples for 5th grade is above 0,05 which is a sufficient condition to conclude that the test results are normally distributed.

Table 1. Test for normal distribution

	groups	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
results	exp.	0,108	50	0,200	0,957	50	0,064
	ref.	0,122	50	0,059	0,957	50	0,068

In statistics, the normal distribution is of essential significance. It lays in the base of solving important cases in representative statistical studies, interval assessment, hypothesis confirmation and etc. The application of parametric tests for confirming hypotheses and studying the relationships between the variables requires preliminary study to find the degree to which the empirical data follows a normal distribution. In this case, the both samples are normally distributed and independent, therefore, T-test for independent samples was used for hypothesis confirmation. The null hypothesis is the assumption for equality of variances of the both samples.

The alternative hypothesis is that the variances are statistically different.

The aim was to determine from which of the both rows the value of Sig. (2-tailed) (Table 3) should be taken under consideration to make a conclusion for the statistical difference between the means.

Table 2. Group statistics

	groups	number	Mean	Standard deviation	Standard error of the mean
results	exp.	50	20,8200	2,54502	0,35992
	ref.	50	20,3200	2,03480	0,28776

Table 3. T-test for comparison of the means

		Leven test		T-test			
		F	Sig.	t	df	Sig. (2-tailed)	Difference between the means
results	equal variances	1,391	0,241	1,085	98	0,281	0,500
	different variances			1,085	93,473	0,281	0,500

The Leven test shows that the variances are not statistically different (Sig. 0,241>0,050), which determines that the value of Sig. (2-tailed) from the first row (equal variances) should be checked. The value is 0,281>0,050, which means that there is no statistical difference between the results from the preliminary tests of the both groups in 5th grade.

6th grade preliminary test

The Shapiro-Wilk test (Table 4) shows normal distribution for the both samples, which means that a parametric test for comparison should be used.

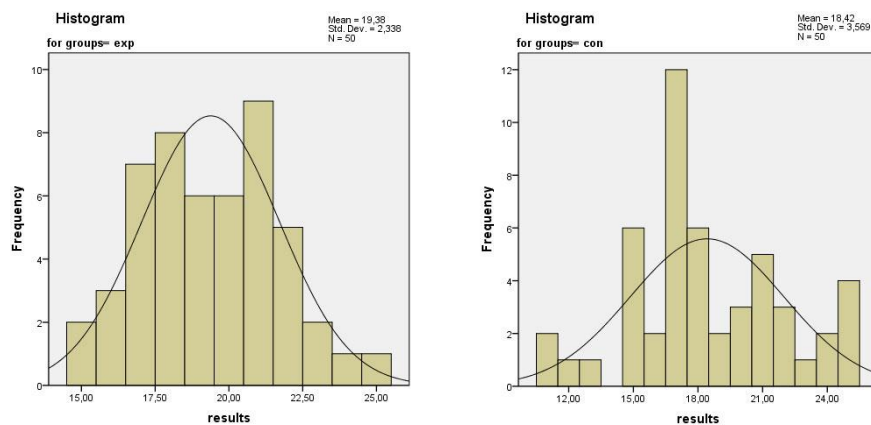


Figure 2. Histograms of the experimental and reference group for preliminary test 6th grade

Table 4. Test for normal distribution

	groups	Kolmogorov-Smirnov	Shapiro-Wilk				
		Statistic	df	Sig.	Statistic	df	Sig.
results	exp.	0,123	50	0,058	0,972	50	0,284
	ref.	0,147	50	0,009	0,957	50	0,065

The applied T-test (Table 6) for two independent samples showed that there is no statistical difference between the results from the preliminary test for the two groups.

Table 5. Group statistics

	groups	number	Mean	Standard deviation	Standard error of the mean
results	exp.	50	19,3800	2,33771	0,33060
	ref.	50	18,4200	3,56908	0,50474

Table 6. T-test for comparison of the means

		Leven test		T-test			
		F	Sig.	t	df	Sig. (2-tailed)	Difference between the means
results	equal variances	6,961	0,010	1,591	98	0,115	0,960
	different variances			1,591	84,508	0,115	0,960

According to the Leven test, the variances are significantly different (heteroscedasticity of the samples) (Sig. 0,010<0,050) (Table 6), which means that the value of Sig. (2-tailed) from the second row (different variances) should be checked. The value is 0,115>0,050, therefore, there is a lack of statistical significance between the results from the preliminary tests for the both groups in 6th grade.

7th grade preliminary test

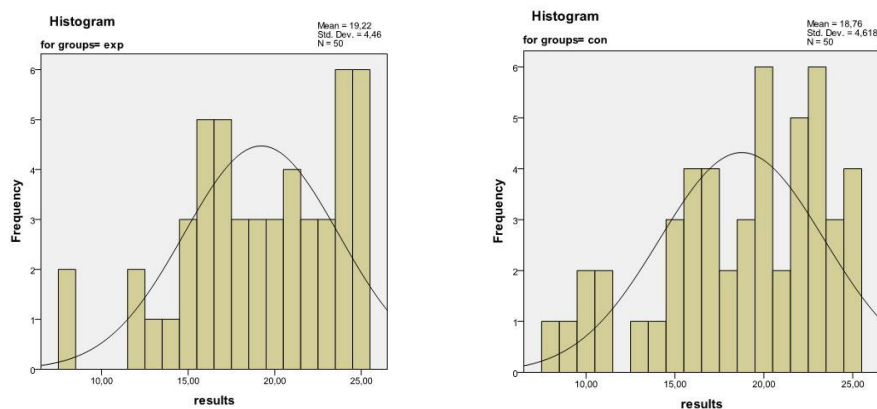


Figure 3. Histograms of the experimental and reference group for preliminary test 7th grade

The Shapiro-Wilk criterion (Table 7) shows that the both independent samples are not normally distributed (Sig.<0,050). Consequently, a non-parametric test for comparison should be used.

Table 7. Test for normal distribution

	groups	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	f	Sig.
results	exp.	0,102	50	0,200	0,938	50	0,011
	ref.	0,126	50	0,046	0,937	50	0,010

The applied Mann-Whitney test (Table 9) showed that the value for Asymp. Sig. (2-tailed) > 0,050, which means that there is no statistical difference between the results from the preliminary test for the both independent samples for 7th grade.

Table 8. Ranks

	groups	number	Rank of Mean	Sum of ranks
results	exp.	50	51,83	2591,50
	ref.	50	49,17	2458,50
	In total	100		

Table 9. Mann-Whitney test

	results
Mann-Whitney U	1183,500
Wilcoxon W	2458,500
Z	-0,460
Asymp. Sig. (2-tailed)	0,646

Summary of the results from the preliminary tests for the three grades

From the conducted statistical verifications of the preliminary level of the results of the experimental and reference group for the three grades, it can be concluded that the students start from the same level in the corresponding subjects.

4.2 Final tests

The final test was conducted for the corresponding samples after the training in the frames of the study year. The results from the final test aimed to confirm the working hypothesis that the use of the inter- and intradisciplinary connections information technologies - natural sciences enhances the quality of the study process and efficiency of the students' training in the lower secondary education stage.

5th grade final test

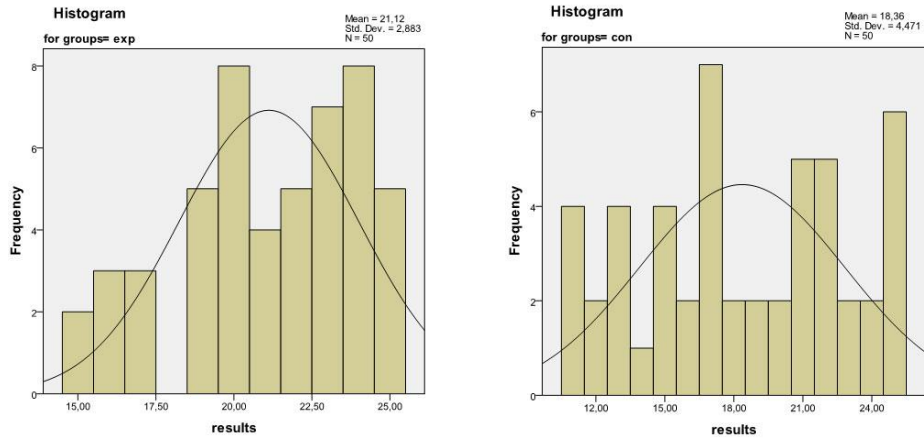


Figure 4. Histograms of the experimental and reference group for the final test in 5th grade

The mean of the experimental group is Mean=21,12 and the one of the reference group is Mean=18,36 (Figure 4). The difference between the means is 2,76 in benefit of the experimental group.

This result itself confirms the assumed hypothesis. However, a verification should be done to find if the difference between the means is a result due to improved methodology or randomness.

Shapiro-Wilk test (Table 10) showed that the results from the final test in 5th grade do not follow normal distribution (Sig.<0.05). In such case, the comparison between the two samples should be done by using a non-parametric test.

Table 10. Test for normal distribution

	groups	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
results	exp.	0,143	50	0,012	0,929	50	0,005
	ref.	0,123	50	0,058	0,939	50	0,013

In this case, the comparative analysis was done with the U-criterion of Mann-Whitney, which returned a result of 0,003 for Asymp.Sig.(2-tailed) (Table 12). Based on this result (significance degree <0,050), it can be concluded that the difference between the two measurements was not due to a randomness but rather it was a result from the applied methodology. With other words, the confirmation of our hypothesis does not have a random character.

Table 11. Ranks

	groups	number	Rank of the Mean	Sum of ranks
results	exp.	50	59,22	2961,00
	ref.	50	41,78	2089,00

	groups	number	Rank of the Mean	Sum of ranks
results	exp.	50	59,22	2961,00
	ref.	50	41,78	2089,00
	In total	100		

Table 12. Mann-Whitney test

	results
Mann-Whitney U	814,000
Wilcoxon W	2089,000
Z	-3,017
Asymp. Sig. (2-tailed)	0,003

6th grade final test

The mean of the experimental group is Mean=20,34 and that of the reference group is Mean=19,04 (Figure 5). The difference between the means is 1,30 in benefit of the experimental group. However, a verification should be done to find if the difference between the means is a result due to improved methodology or randomness.

Shapiro-Wilk test showed that the results for the experimental group from the final test in 6th grade are not normally distributed (Sig. < 0,050).

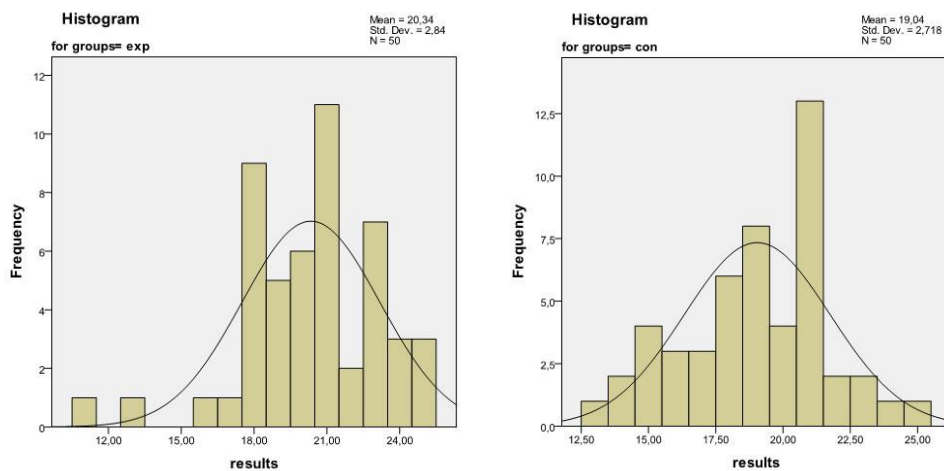


Figure 5. Histograms for the experimental and reference group for the final test in 6th grade

Table 13. Test for normal distribution

	groups	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
results	exp.	0,125	50	0,049	0,936	50	0,009
	ref.	0,145	50	0,011	0,964	50	0,134

Consequently, for the comparison of the both samples, the U-criterion of Mann-Whitney test was used which returned a result of 0,022 for Asymp.Sig.(2-tailed) (Table 15).

Table 14. Ranks

	groups	number	Rank of the Mean	Sum of the ranks
results	exp.	50	57,08	2854,00
	ref.	50	43,92	2196,00
	In total	100		

Table 15. Mann-Whitney test

	results
Mann-Whitney U	921,000
Wilcoxon W	2196,000
Z	-2,293
Asymp. Sig. (2-tailed)	0,022

Based on this result (significance degree $<0,050$), it can be concluded that the difference between the two measurements is not due to a randomness but rather it is a result from the applied methodology. With other words, the confirmation of our hypothesis does not have a random character.

7th grade final test

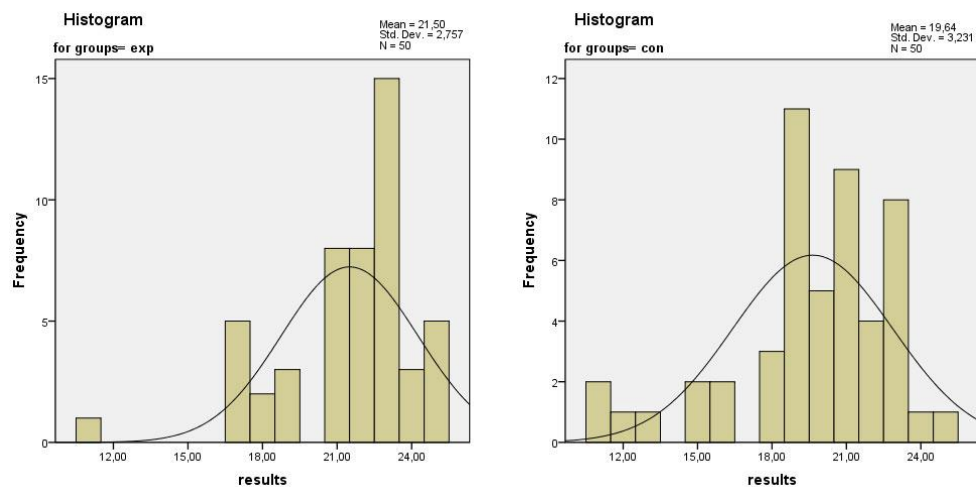


Figure 6. Histograms for the experimental and reference group for the final test in 7th grade

The mean of the experimental group is Mean=21,50 and that of the reference group is Mean=19,64. The difference between the means is 1,86 in benefit of the experimental group. However, a verification should be done to find if the difference between the means is a result due to improved methodology or randomness.

The value of Sig. for the two tests (Kolmogorov-Smirnov, Shapiro-Wilk) of the both samples for 7th grade final test is below 0,05, which is a sufficient condition to conclude that the test results do not follow normal distribution.

Table 16. Test for normal distribution

	groups	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
results	exp.	0,208	50	0,000	0,860	50	0,000
	ref.	0,201	50	0,000	0,900	50	0,000

From the made conclusions for the both groups, it follows that a non-parametric method should be used for comparing the results of the both independent samples. For this aim, the comparative analysis was done with the U-criterion of Mann-Whitney which returned a result of 0,001 for Asymp.Sig.(2-tailed) (Table 18).

Table 17. Ranks

	groups	number	Rank of the Mean	Sum of the ranks
results	exp.	50	59,87	2993,50
	ref.	50	41,13	2056,50
	In total	100		

Table 18. Mann-Whitney test

	results
Mann-Whitney U	781,500
Wilcoxon W	2056,500
Z	-3,266
Asymp. Sig. (2-tailed)	0,001

Based on this result (significance degree <0,05), it can be concluded that the difference between the two measurements was not due to a randomness but rather it is a result from the applied methodology. With other words, the confirmation of our hypothesis does not have a random character.

5. Discussion

From the made statistical verifications for the final level of the results of the experimental and reference group for the three grades, it can be concluded that the difference in the levels of the results in the individual measurements for the corresponding levels is not due to randomness but rather it is a result from the applied methodology. Thus, the working hypothesis stating that the use of the inter- and intradisciplinary connections information technologies - natural sciences enhances the quality of the study process and efficiency of the students' training in lower secondary education stage was confirmed.

6. Conclusions

The aim of the current work was to present the results from the training of students from the lower secondary education stage (5th, 6th and 7th) by using a methodology, including interdisciplinary connections in the field of IT and natural sciences. Various software products and technologies were used that assisted the teaching in natural sciences during the general education preparation and interest activities through the performance of projects. The analysis of the obtained results from the teaching by using this methodology showed better students' assimilation of the study content.

The obtained objective information from the processing of the results from the conducted pedagogical study is only one example for confirming the assumption that the use of innovative approaches in the training has a beneficial influence on the quality of the training and on the improvement of the process of perception of the given study content.

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A comparative analysis of primary Digital Education design and its implementation

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Abstract: *The article explores the importance of digital education in primary education, emphasising alignment with European standards, such as the DigComp 2.2 framework. Through a comparative analysis of curricula from various countries, it highlights best practices and gaps in integrating digital skills, such as programming, online security, and digital literacy. The study focuses on the experience of the Republic of Moldova, which has introduced digital education as a mandatory subject, providing a model for effectively integrating technology into the educational process from an early age.*

Keywords: digital education, curriculum, DigComp framework, primary education.

1. Introduction

Digital Education (DE) is essential in preparing individuals for an increasingly technology-dependent society. It not only facilitates the integration of digital competence (a key competence) into daily activities but also contributes to developing essential skills for lifelong learning, innovation, and active participation in the digital economy. In this context, the European DigComp 2.2 framework provides a clear and updated structure for identifying and developing the digital competencies needed by 21st-century citizens.

The implementation of primary digital education is vital for several reasons. Children at this educational stage are increasingly exposed to Digital Technologies (DT) at an early age, and schools have the responsibility to provide a structured and safe environment for them to develop age-appropriate digital skills. DE contributes to fostering critical thinking, adopting responsible digital behaviours, and preparing for creative use of technology. Moreover, by integrating DE into the curriculum, students acquire transversal skills such as online collaboration, problem-solving, and adaptability, which are fundamental for their future academic and professional success.

As with many other educational subjects, the importance given to digital skills at the primary level varies significantly from country to country. In some states, DE is not included as a distinct subject or is not taught at all. In other countries, technology use is integrated throughout the entire curriculum. There are national curricula where this subject is mandatory, while in others, it is only optional.

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Typically, in the primary cycle, IT is integrated into other subjects, and later Computer Science becomes a separate subject. The names of subjects that integrate IT topics vary considerably: “Information Technology” (Finland, Japan), “Technological Literacy” (USA, Massachusetts), “Computer and Information Sciences; Digital World” (Serbia), “Technology and Informatics” (Montenegro), “Computer Applications” (Singapore), or “Computer Science” (Italy).

These names reflect differences in priorities and approaches. Some emphasise technology and programming, while others focus more on the practical use of ICT (Sturman & Sizmur, 2011).

2. Methodology and results

In this study, the aim was to investigate the role of DE, analyse international initiatives and practices, and contribute to the development of the curriculum framework and educational resources for primary DE. The methodological stages of the research are detailed below:

- A documentary analysis was conducted on specialised literature, international educational policies, and relevant reports to understand the role and importance of digital education in a globalised society. The study focused on its impact on the development of key competencies and preparing citizens for the challenges of the digital economy;
- The research included an examination of international projects, policies, and relevant initiatives in the field of DE. Best practices and models implemented in various countries were identified to provide a comparative context for the development of the national curriculum;
- Curricula for DE from several countries were compared, focusing on structure, content, and targeted competencies. The curriculum analysis from the Republic of Moldova was detailed to explain how learning contents were identified and developed;
- The researchers developed and implemented content units and digital educational resources for the DE subject intended for the primary cycle. The process included analysing educational needs, defining specific competencies, and creating interactive resources, followed by their testing and adjustment within the school context in the Republic of Moldova;
- A detailed analysis of the educational contents of the DE subject was conducted in relation to the areas of the DigComp 2.2 framework. This approach aimed to ensure coherence between curricular objectives and European standards in DE, highlighting the correlations and differences between them.

2.1 The importance of primary Digital Education at the global level

As mentioned earlier, the importance given to digital skills at the primary level varies significantly from country to country. In some states, DE is not included as a distinct subject (mandatory or optional) or is not taught at all, and digital skills are developed through other subjects. For example, the Massachusetts school curriculum (Massachusetts Department of Elementary and Secondary Education, 2016) does not include a separate subject focusing exclusively on Information Technology (IT) or Computer Science, whereas the school curriculum in Finland (Finnish National Agency for Education, n.d.) includes separate optional subjects for IT and Computer Science. In Estonia (Riigiteataja, 2019), since 2011, the curriculum stipulates that each subject includes learning units for developing digital competencies. For instance, in studying the native language and foreign languages, digital communication tools are examined, while the Computer Science curriculum (an optional subject) focuses on virtual identity, internet safety, digital security, etc.

Both Serbia (Serbia, 2020) and Montenegro (Ministry of Education, 2020) offer separate courses (mandatory or optional). In Serbia, middle school students (aged 11-14) study the mandatory subject “Computer Science and Informatics” and can additionally choose other modules in the IT field (Programming, Interactive Graphics, and Graphic Design). Similarly, in Montenegro, word processing applications are studied as part of the optional subject “Informatics with Technology” starting from the 5th grade, while programming skills are covered later, starting from the 8th grade, through the mandatory subject “Introduction to Programming”.

In some countries, such as Israel (Armoni & Gal-Ezer, 2014a), programming is taught from an early age. Other countries, such as Singapore, have made significant strides in integrating DE into the curriculum. For instance, in 2020, Singapore implemented a mandatory 10-hour programming program for students (Sturman & Sizmur, 2011).

South Korea is also a pioneer in this field. As early as 1987, the South Korean government launched a national plan for the computerisation of schools. Starting in 2015, South Korea included programming as a mandatory part of the curriculum from the primary level (Rha & Yoshida, 2005).

2.2 Initiatives for developing the curriculum framework for primary Digital Education

Many countries have integrated DE into their school curricula to prepare future generations for the challenges and opportunities of technology. Australia, South Africa, and the United Arab Emirates are just a few examples of countries that have adopted these initiatives. In 2016, Australia (Australian Curriculum, Assessment and Reporting Authority [ACARA], 2016) implemented the Australian

Curriculum for Digital Technologies, focusing on programming, data representation, and digital systems.

In Europe, DE has developed at different rates, depending on the country. The European Commission has been a key force in this process, leading programs aimed at promoting digital skills and digital literacy across the community. Over time, European countries have adopted these visions to include DE in their education systems. One of the key frameworks developed by the European Commission is the “Digital Competence Framework for Citizens” (DigComp), which was first published in 2013. This initiative paved the way for measuring and improving the digital competencies of every citizen. As a result, DigComp has become an important tool for educators in Europe, providing guidance on how to review and improve the teaching of digital skills.

Some European countries have a long history of teaching Computer Science in primary schools. For example, in Poland, Computer Science has been taught since the 1990s (Sysło & Kwiatkowska, 2015; Sysło, 2018), while in Slovakia, it was introduced in the early 2000s (Kabátová, Kalaš & Tomcsányiová, 2016). Other countries introduced Computer Science in primary school more recently.

Similar trends have occurred globally. In 2015, the U.S. Congress passed the “Every Student Succeeds Act”, which includes Computer Science as one of the subjects that should be taught starting in primary school. In 2016, Israel introduced Computer Science from the 4th grade through to the last grade of secondary education (Armoni and Gal-Ezer, 2014a). Japan introduced Computer Science for primary schools in 2020 (Oda, Noborimoto & Horita, 2019).

Estonia introduced programming as a mandatory subject for primary school students as early as 2012, and other European countries, such as England, Finland, and Italy, followed suit. In England, children between the ages of 5 and 16 learn programming and fundamental computer science concepts, including internet safety.

Since 2014, Digital Education has been a mandatory subject in Denmark (Ministry of Children and Education, 2017). This is due to the fact that, in the 2014 school year, the Danish government introduced a new national curriculum that includes the module “Understanding Technology”. It is mandatory for all students (aged 6 to 16). The module provides students with a deep understanding of technologies and how they impact society, thus preparing them for an increasingly digitalised world.

Since 2015, South Korea (Choi, 2021) has initiated several measures to improve digital education, including transforming Computer Science from an optional to a mandatory subject.

Digital education became essential for Italy starting in the 2019/2020 school year. In 2020, a new national curriculum was developed, which introduced a new subject: “Digital Citizenship and Digital Civic Education” (“Cittadinanza Digitale e Educazione Civica Digitale”). This subject focuses on developing essential skills for responsible citizenship in the digital environment.

In Greece (Ministry of Education and Religious Affairs, 2020), Computer Science is a separate, mandatory subject starting from the 1st grade throughout primary education. In Lithuania, the curriculum was updated to introduce Computer Science from the 1st grade at the primary level in the 2020/2021 school year, with mandatory implementation starting in 2023. In Bosnia and Herzegovina, it began being taught in primary schools in the 2019/2020 school year, and in Serbia, it was introduced starting with the 2020/2021 school year.

In Latvia (Skola 2030, 2020), the 2020–2021 curriculum reform includes the “Computing” course for grades 4–6.

In Liechtenstein, the subject “Media and Informatics” is integrated into general courses for grades 1–3 and is a separate subject in grades 4–5. In Slovakia, Bulgaria, North Macedonia, and Hungary, this subject is mandatory from the 3rd grade (Marrone et al., 2021).

In Finland (Finnish National Agency for Education, n.d.), primary digital education has been integrated into the curriculum since the 1990s, with an emphasis on digital literacy, computational thinking, and programming. The Finnish national curriculum was reorganized in 2016 to increase the focus on these areas.

In Romania (Ministry of Education of Romania, 2024), digital competencies are integrated into the primary education curriculum, not as a separate subject but by incorporating mandatory digital education topics into various subjects. According to the Strategy for the Digitalization of Education in Romania 2021-2027, starting with the 2021-2022 school year, such elements have been introduced into the primary school curriculum. On August 30, 2024, the Digital Competence Framework for Students was approved, establishing the necessary digital competencies for each educational cycle, including primary education. This framework aims to develop students' digital skills, adapted to their age and educational level.

Table 1 presents the names of subjects related to Digital Education, how they are taught, and the year of their implementation in the curricula of various countries.

Table 1. Integration of primary Digital Education into the national curriculum of different countries

Country	Status	Year	Starting grade	Name of the subject
Republic of Moldova	c	2018	1	Digital Education
United Arab Emirates	c	2017	1	Computer Science
England	c	2014	1	Computing
Finland	c	2016	1	ICT and Technology
Izrael	c	2016	4	Science and Technology
Singapore	c	2020	1	Computational Thinking and ICT
Japonia	c	2020	1	Tehnologie

South Korea	c	2015	3	Informatics
USA	c	2015	1	Computer Science/Computational Thinking
Australia	c	2016	1	Tehnologii digitale
Bulgaria	o		3	Computer modelling
Estonia	c	2012	1	Informatics
Greece	o	2019	1	ICT
Croatia	c		1	Informatics
Latvia	o		1	Computing
Lithuania	o	2023	1	Informatics
Hungary	o	2020/ 2021	1	Digital culture
Poland	o	2017/ 2018	1-3 4	Informatics education/Informatics
Romania	o	2024	1-4	Information and Data Literacy (in all disciplines)
Slovenia	c		4	Computer science
Slovakia	o		3	Informatics
Bosnia and Herzegovina	o		1	Informatics
Liechtenstein	o		4	Media and informatics
North Macedonia	o		3	Working with computers and programming basics
Serbia	o	2020/ 2021	1	Digital world

Status: c = compulsory; o = optional

2.3 Curricular analysis of primary Digital Education in the Republic of Moldova

Although significant progress has been made regarding the development of the curriculum framework for Digital Competence as a key competence, there is no common reference framework for the content of primary Digital Education (DE). At the European level, Digital Competence is described in the Digital Competence Framework for Citizens (DigComp) with 5 main areas and 21 skills. The latest version was published in March 2022 (Vuorikari, Kluzer & Punie, 2022). Although activities in Computer Science lessons contribute significantly to the development of Digital Competence, the objectives of this subject are still different. To support European countries' efforts in the development of Computer Science education, the Informatics for All coalition (Informatics for All coalition, 2022) published a reference framework in February 2022, the Informatics Reference Framework for School, which includes 10 domains considered fundamental in computer science education (Table 2).

Table 2. Fundamental domains in Computer Science education

Fundamental domains in Computer Science education	
D1. Data and information	D6. People–system interface
D2. Algoritmi	D7. Design and development
D3. Programming	D8. Modelling and simulation
D4. Computing systems	D9. Awareness and empowerment
D5. Networks	D10. Safety and security

Table 3 presents the results of the analysis of school curricula from different countries regarding computer science education for primary education level (in accordance with the 10 fundamental domains of the *Informatics Reference Framework for School*).

Table 3. Analysis of fundamental domains in Computer Science education worldwide

Country	Fundamental domains in Computer Science education									
	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
South Korea	+	+	+	+	+				+	+
Singapore	+	+	+	+	+				+	+
Japonia	+	+	+	+	+				+	+
Australia	+	+	+	+	+				+	+
United Arab Emirates	+	+		+	+				+	+
Republic of Moldova	+	+	+	+	+				+	+
England	+	+	+	+	+				+	+
Finland	+	+	+	+	+				+	+
Bulgaria	+	+	+					+		+
Estonia			+							
Greece	+	+	+		+	+	+	+	+	
Croatia	+		+	+	+	+			+	+
Latvia			+		+					+
Lithuania										
Hungary		+	+			+				+
Poland	+		+	+	+		+			+
Romania	+				+		+			
Slovenia	+	+	+		+			+	+	+
Slovakia	+	+	+						+	+
Bosnia and Herzegovina	+									+
Liechtenstein	+	+	+	+	+				+	
North Macedonia		+	+	+						+
Serbia		+	+		+				+	+
Turkey							+			

The mentioned curriculum analysis shows that:

a) The educational systems in Moldova, Bulgaria, Czech Republic, Greece, France, Croatia, Poland, Slovakia, Switzerland, Liechtenstein, and Montenegro address topics related to *data and information* at the primary education level.

b) More than half of the countries in Table 2 have already designed learning topics related to *algorithms* in primary education (Croatia, Hungary, Macedonia, Moldova, etc.). In Croatia, primary school students learn to follow and present the sequence of steps to solve a simple task, while in Hungary, primary school students are taught to recognise, reproduce, and apply basic steps from daily activities, structure a daily algorithm in simple steps, understand the order of these steps, and determine the desired outcome of the algorithm.

c) In general, school curricula do not specify a particular *programming* language; some curricula mention block programming or visual programming and only rarely include programs like Scratch (e.g., in the 7th-grade computer science curriculum in North Macedonia). In Poland, informatics is taught at all three educational levels, including primary education. Primary school students create and write stories and simple solutions in visual programming environments, using sequential, conditional, iterative commands, and events. They develop programs that control robots or objects on the screen.

d) In some curricula for primary education (from Croatia, Poland, Slovenia, Liechtenstein, and North Macedonia), there are approaches related to the area of *computing systems*.

e) Many countries have developed learning topics related to *networks* at the primary education level (Greece, Croatia, Latvia, Poland, Slovenia, Liechtenstein, Serbia).

f) Only a few countries (Greece, Croatia, and Hungary) already include explicit learning objectives related to *human-machine interfaces* at the primary level, and only three countries (Greece, Poland, and Turkey) have learning outcomes related to design and development at the primary level.

g) *Modelling and simulation* is another area that the school computer science curricula do not frequently address. Only a few countries have explicit learning outcomes for this area in primary education (Bulgaria, Greece, Slovenia), and a few countries already have explicit learning outcomes related to the area of *Awareness and empowerment* at the primary education level (Greece, Croatia, Slovenia, Slovakia, Liechtenstein, Serbia).

h) Learning content corresponding to the domain of *Safety and security* is found in the majority of primary school curricula.

i) În România competențele digitale sunt integrate în curriculumul învățământului primar, însă nu printr-o disciplină separată, ci prin includerea unor subiecte obligatorii de Educație Digitală în diverse materii.

j) The education system in the Republic of Moldova addresses subjects related to most of the fundamental areas of Informatics at the primary level, which suggests an active integration of technologies and digital skills into the school curriculum from an early age (Ministry of Education, Culture and Research of the Republic of Moldova, 2018).

2.4 Primary Digital Education in the Republic of Moldova versus the areas of the DigComp 2.2 framework

Since 2018, primary digital education has become mandatory in the Republic of Moldova. The design and implementation activities for digital education have been supported by the government through joint initiatives with IT associations. The European Digital Competence Framework for Citizens (in 2018, DigComp 2.1, and from 2020, DigComp 2.2), conceptually developed by the European Union to support the development and assessment of citizens' digital competencies, describes 21 digital skills across 5 dimensions: A1. Information and data literacy; A2. Communication and collaboration; A3. Digital content creation; A4. Security; A5. Safety and problem solving.



Figure 1. Interactive digital learning resources for Digital Education (in Republic of Moldova)

As a result, together with the authors of this article, interactive digital learning resources were designed and developed (Figure 1, Ministry of Education and Research of the Republic of Moldova, n.d.), considering the DigComp 2.1 framework and the age-specific characteristics of the students (Table 4).

Table 4. Educational content of primary Digital Education versus DigComp 2.2 areas

Grade	Contents	Areas DigComp 2.2				
		A1	A2	A3	A4	A5
1	Digital world	+				
	Digital communication		+			
	Digital technology in everyday life				+	+
	Digital thinking			+		
2	Units of information	+				

	Writing and drawing digitally			+		
	Digital thinking			+		+
3	Creating and organizing folders and files	+				
	Writing and drawing digital			+		
	The expanding digital world – networks and the internet		+		+	
	Digital thinking			+		+
4	Web pages	+				
	Rights and obligations in the digital world				+	
	Learning digitally					+
	Digital thinking			+		+

The national curriculum for primary Digital Education (from the Republic of Moldova) involves the formation and development of a wide range of digital skills in alignment with the 5 areas of the DigComp 2.2 framework (Figure 2).

The educational content of primary digital education developed by the authors has been created in accordance with this curriculum.

An important feature of the curriculum is the “Learning Digitally” module in the 4th grade, which focuses on the formation and development of ICT-assisted learning skills. Thus, the 4th-grade student should be able to utilise their educational achievements in the field of Digital Education to enhance their academic performance.

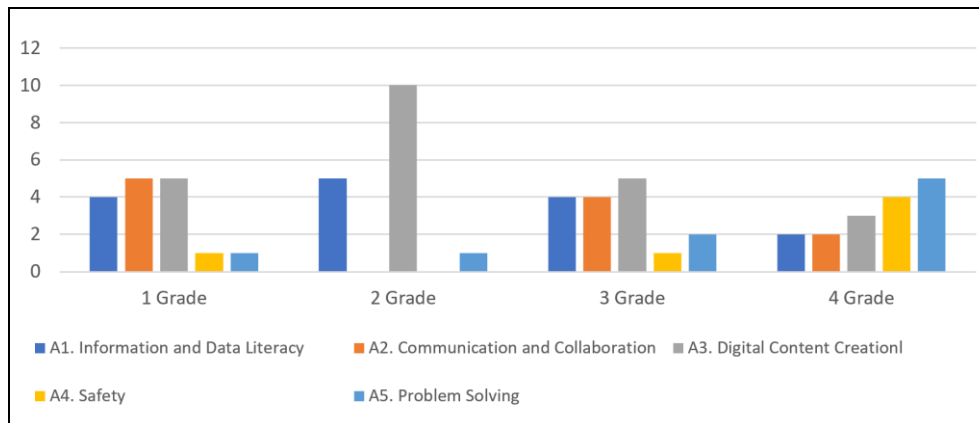


Figure 2. Number of hours of educational content per DigComp 2.2 areas

3. Conclusions

Digital education is becoming an integral and essential part of modern education systems. Countries that have adopted early approaches, either through the integration of primary digital education or by introducing programming as a mandatory subject, recognise the importance of developing digital competencies

from an early age. The Republic of Moldova has made remarkable progress in this direction, providing students with the opportunity to learn both the use and creation of digital content, preparing them for the professional demands of the future.

A comparative analysis of educational curricula from various European countries shows significant variation in how digital education is approached. While most countries include basic competencies such as information literacy, digital security, and online collaboration, there are notable differences in how programming, algorithms, and digital modelling are taught. Education systems in countries such as Greece, Poland, and Turkey have made significant strides in areas like technological solution design and human-machine interaction, although these fields remain less explored globally.

The Republic of Moldova, Bulgaria, the Czech Republic, Greece, France, Croatia, Poland, Slovakia, Switzerland, Liechtenstein, and Montenegro already have considerable progress in integrating topics related to data and information.

The curriculum for digital education in the Republic of Moldova aligns with European standards by covering all five dimensions of the DigComp 2.2 framework, providing students with the necessary competencies to become responsible users and creators of technology. However, the lack of continuity in the development of these competencies between primary and secondary education remains a challenge that deserves additional attention.

In conclusion, digital education can no longer be considered optional but a necessity to equip new generations with the skills demanded by an increasingly digitalised world.

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