The impact of generative artificial intelligence on students and teachers in the educational process

Vladan Čolić[1,*] Enes Sukić[2]

[1] Academy of Professional Studies Šumadija, Kragujevac, Serbia, vcolic@asss.edu.rs
[2] University „Union - Nikola Tesla", Faculty of Information Technology and Engineering, Department of Information Systems, Belgrade, Serbia, enes.sukic@fiti.edu.rs

Abstract

In the last 10–15 years, significant investments have been made in the integration of modern technologies into the educational process. These investments have been driven by the rapid development of the internet and information technologies, as well as global challenges such as the COVID-19 pandemic, which necessitated a shift toward online learning. The primary objective of these efforts is to improve the efficiency of the educational process by enabling students to develop essential skills, such as problem-solving, teamwork, and analytical thinking, all supported by technology.

When discussing modern technologies, special attention must be given to Artificial Intelligence (AI) and its subfield, Generative Artificial Intelligence (GAI), which are increasingly integrated into the educational environment. In this context, Generative Artificial Intelligence has the potential to significantly reshape teaching and learning by offering personalized learning experiences, dynamic instructional content, and tools that foster creative thinking. For educators, GAI offers new possibilities for interactive teaching, tracking student achievements, and analyzing academic performance.

These tools, designed for both students and teachers, are easily accessible, intuitive to use, and constantly evolving. This paper presents a theoretical review of the implementation of GAI in education and examines how its application influences the work of students and teachers. Furthermore, the paper will explain the potential of GAI to enhance digital literacy, analytical thinking, and adaptive learning strategies necessary for competitiveness in the 21st-century labor market.

1. Introduction

This paper aims to present the impact of Generative Artificial Intelligence (GAI) on the educational process as a whole without focusing on specific disciplines or educational levels. Although each educational field possesses its own particularities and characteristics regarding GAI implementation, the fundamental principles, advantages, challenges, and other GAI-related aspects are applicable to the educational concept in its entirety. This holistic approach allows us to examine the potential of GAI application for the entire educational system and provides a foundation for future research that will address GAI implementation in specific educational disciplines in greater detail.

The paper is organized as follows: Section 2 presents the theoretical framework supporting GAI implementation in education; Section 3 explains the concept of Generative Artificial Intelligence; Section 4 analyzes the impact of GAI on learning and education, including benefits and challenges; Section 5 discusses the competencies required for effective GAI application; Section 6 explores future research directions; Section 7 examines case studies of GAI implementation; and Section 8 provides concluding

*Corresponding author. Email: vcolic@asss.edu.rs

remarks on the transformative potential of GAI in education.

The 21st century, often referred to as the century of technology, has brought profound changes across all sectors of human society, including education. The rapid advancement of digital technologies has significantly transformed the way knowledge is delivered, acquired and assessed. Traditional teaching methods are gradually being replaced by more dynamic approaches driven by technology that foster a shift from passive to active learning.

As modern technologies introduce new global trends into education, it is crucial to redefine pedagogical perspectives and evaluate both the opportunities and challenges they present [1]. One of the most transformative developments in this context is the emergence of Artificial Intelligence. Although the concept of Artificial Intelligence is not new (existing for nearly 50 years), recent advancements in computing power, data analytics, and neural networks, have enabled AI to evolve and become widely accessible in everyday use.

As a subfield of AI, Generative Artificial Intelligence (GAI) represents one of the most innovative and disruptive technologies in education today. The most important and useful characteristic of GAI is that it can independently learn and create new content, including images, text, video, and audio. This capability enables GAI to personalize learning experiences, provide real-time feedback, and support the development of higher-order thinking skills.

2. Theoretical Framework: Educational Theories Supporting GAI Implementation

The implementation of Generative Artificial Intelligence in education is grounded in several established educational theories that explain how AI enhances learning outcomes.

Vygotsky's Zone of Proximal Development (ZPD) provides a framework where GAI functions as the "*more knowledgeable other*," offering personalized support tailored to each student's level while providing dynamic scaffolding that gradually fades as learners develop competence [2,3].

Cognitive Load Theory demonstrates how GAI optimizes learning by managing intrinsic, extraneous, and germane cognitive loads, helping students allocate their mental resources more efficiently during complex learning tasks [4]. By managing these different types of cognitive load, GAI tools help students allocate more of their cognitive resources to meaningful learning processes rather than to overcoming instructional barriers.

Through Bloom's Taxonomy, we can understand how GAI supports development across cognitive skill levels, from basic knowledge acquisition to higher-order thinking skills like analysis, evaluation, and creation [5]. For instance, GAI-based writing assistants can offer feedback that prompts students to critically analyze their arguments, evaluate the quality of evidence, and create more sophisticated compositions. By engaging students in these higher-order cognitive processes, GAI tools foster deeper learning and cognitive development.

Constructivist Learning Theory correlates with GAI's ability to generate adaptive materials that respond to students' inquiries and misconceptions, enabling learners to actively construct knowledge rather than passively receive it [6]. GAI can support social constructivism by facilitating collaborative learning experiences. Even in individual interactions with GAI, the system can simulate Socratic dialogue, prompting students to articulate and refine their understanding through questioning and discussion, thereby supporting the social construction of knowledge.

Finally, Connectivism explains how GAI embodies learning in the digital age by helping students navigate vast information networks, identify patterns across concepts, and develop critical information literacy skills essential for lifelong learning [7]. GAI supports the connectivist principle that knowing where to find information is more important than memorizing facts. By providing tools that help students locate, evaluate, and synthesize information efficiently, GAI fosters the development of critical information literacy skills essential for lifelong learning in the digital era.

Holmes and Tuomi (2022) highlight that AI in education has potential beyond merely automating teacher tasks, suggesting it could have a transformative effect by "augmenting human cognition in learning" - a perspective that aligns with our theoretical frameworks of cognitive development [8]. Their work emphasizes the need for critical assessment of AI's pedagogical applications, which supports our discussion of educational theories that ground GAI implementation.

These theoretical foundations collectively demonstrate that GAI is not merely a technological enhancement but a pedagogically sound approach to improving educational outcomes through personalization, adaptive support, and cognitive development facilitation.

3. Generative Artificial Intelligence: A theoretical concept

We are already familiar with the term "Artificial Intelligence" (AI), which refers to computer systems capable of mimicking human intelligence, including speech and text recognition, decision-making, learning, and problem-solving. AI systems continuously learn and self-correct during the learning process, relying on "training data" as the foundation for their learning. The larger the dataset, the more efficient, successful, and relevant the learning process becomes. However, care must be taken when supplying systems with data to avoid what is known as *"system hallucination."*

AI system hallucination occurs when a model generates false, inaccurate, or illogical information with no basis in real data. This happens when the system provides answers that sound plausible but are untrue or irrelevant to the given question. As IBM explains, these hallucinations occur "*when AI algorithms produce outputs that are nonsensical*

or altogether inaccurate" due to various factors including data limitations and model complexity [9]. In educational contexts, this creates significant risks of misinformation when students or teachers rely on seemingly authoritative but factually incorrect AI-generated content.

On the other hand, the concept of *"Generative Artificial Intelligence"* (GAI) ushers us into a new era and innovative ways of utilizing AI. GAI is considered a subfield of AI and represents one of its most cutting-edge technologies. Unlike traditional AI systems that operate based on pre-programmed data, GAI possesses the ability to independently learn and, most importantly, create new content. The content generated by GAI can take the form of text, images, audio, or video.

The hallmark of GAI lies in its reliance on algorithms capable of producing novel, authentic, and creative outputs. These algorithms are primarily based on neural networks—complex systems designed to mimic the function of neurons in the human brain. One of the most prominent examples of GAI is Generative Adversarial Networks (GANs). GANs employ two neural networks—a generator and a discriminator—that work against each other during the training process. The generator creates new content resembling original data, while the discriminator evaluates the authenticity of these samples. Through iterative competition, these networks improve, resulting in the creation of increasingly realistic content.

AI technologies, such as intelligent tutoring systems and robots, support and enhance education, offering significant potential to improve learning, teaching, and assessment [10]. These capabilities allow GAI to transform the learning and teaching process by providing each student with a personalized learning experience tailored to their needs and interests.

However, alongside these advantages, it is essential to consider the risks associated with integrating GAI into education—a topic examined in the subsequent sections of this paper. The release of ChatGPT in November 2022 brought the concept of GAI into the spotlight, prompting research into this field and analysis of its potential impact on education [11].

4. The impact of Generative Artificial Intelligence on learning and education: Foundations, advantages, and challenges

It is anticipated that the implementation of Generative Artificial Intelligence (GAI) will have the greatest impact on occupations based on intellectual work and high levels of education. Among all sectors of the economy and society, three are predicted to experience the greatest influence from GAI: finance, education, and professional services [12]. It is argued that the influence of artificial intelligence, and consequently GAI as its subfield, will be so profound that it is "*poised to have a greater impact than the introduction of electricity*" [13].

Generative Artificial Intelligence, as a modern concept, finds broad application in contemporary education. One of its primary advantages lies in eliminating the "*one-size-fits-all*" approach to learning and teaching. Using GAI to assist students in learning has become a significant trend [14]. Through GAI, students can adapt their studies to their own pace, while the system itself can further adjust to individual styles, preferences, and needs in the learning process. GAI allows students to immediately observe the effects of their learning and receive real-time feedback, which is highly beneficial. This capability enables students to monitor their progress at any moment and identify areas that require improvement.

At the same time, analyzing student success and predicting their outcomes has become significantly more complex due to the massive amounts of data surrounding us and the limitations of traditional data processing methods. This makes it inevitable to employ modern AI-assisted data processing techniques [15]. Globally, the application of GAI in education enables a significant transformation of the learning process and the experience students gain through it.

The application of GAI in the educational process is based on models such as personalized learning, adaptive learning, and project-based learning. The first model adjusts teaching materials to each student, the second uses GAI to adapt the learning process in real-time, while the third enables students to use GAI for research, analysis, and idea generation. This shifts the role of teachers from an instructive to a facilitative one. They assist students in evaluating the information they receive, while also acting as supervisors who oversee the ethical application of GAI in education. Through their role as evaluators, teachers monitor student progress using data generated by GAI. In this context, it can be said that the foundation of responsible and effective GAI implementation in education lies in a clearly defined usage strategy and continuous teacher training.

On the other hand, GAI can substantially assist educators by making their work significantly more productive. Teachers can use GAI to create personalized materials for students, saving time and maximizing the effectiveness of the educational process. With the help of GAI, teachers can more easily track the progress of individual students. By using these tools, educators can create engaging and interactive materials (such as quizzes and presentations) that ensure maximum student attention and engagement during lessons.

In the learning process, especially in higher education, it is crucial to have access to accurate, current, and reliable information at all times, as these institutions prepare students for the practical application of knowledge. Incorrect and outdated information during training can lead to poor decisions in future workplaces and jobs. The application of GAI in education and learning processes can help mitigate this issue by providing the "*right information at the right time*."

4.1. Integrated benefits of GAI in education

When we consider all aspects of Generative Artificial Intelligence (GAI), some of the most important areas where it can be potentially useful for students [16] include:

- **Personalized learning:** GAI systems adapt to individual learning paces, styles, and needs, providing tailored educational experiences that optimize learning outcomes.
- **Real-time feedback:** Students receive immediate assessment of their work, allowing them to identify areas for improvement and track their progress continuously.
- **Enhanced information access:** GAI provides accurate, current, and reliable information precisely when needed, particularly valuable in higher education where practical application of knowledge is crucial.
- **Support for specific needs:** Students with learning disabilities, language difficulties, or other special requirements receive targeted assistance that addresses their unique challenges.
- **Critical thinking development:** GAI tools encourage curiosity, idea generation, and analytical thinking by providing frameworks for exploration rather than merely delivering answers.

Additionally, the potential benefits of GAI for educators can be summarized through the following activities:

- **Content generation efficiency:** Teachers can automatically create personalized teaching materials, assessment tools, and interactive resources, significantly reducing preparation time.
- **Learning analytics:** GAI enables detailed tracking of individual student progress and pattern identification in large datasets, facilitating evidence-based pedagogical decisions.
- **Interactive resource creation:** Educators can develop engaging simulations and interactive materials that maintain student attention and participation throughout lessons.
- **Administrative automation:** Routine administrative tasks can be handled by GAI systems, allowing teachers to focus on higher-value educational activities.

Similarly, higher education institutions can benefit from GAI in several ways, including:

- **Research enhancement:** GAI can analyze vast volumes of data, identify patterns, extract regularities in scientific research, and generate research predictions and future directions.
- **Curriculum development:** Institutions can automate the generation of content for subjects, including teaching plans and lesson materials.
- **Standardization assistance:** GAI helps define learning objectives, examination rules, and prepares necessary documentation according to institutional standards.

4.2 Challenges and potential negative effects

Despite these advantages, it is crucial to consider the potential negative effects of GAI implementation in education. Some of the most significant negative effects of GAI in higher education include [17]:

Distraction of students. The presence of computers, laptops, and other technological devices in the learning environment can divert students' attention. Given the diversity among students, some may prioritize entertainment-such as online gaming, social media browsing or web surfing- over completing their academic tasks. In such cases, the presence of technology has a negative impact on the student and their achievements.

Erosion of social skills. As educational activities increasingly transition to digital environments, direct face-to-face communication diminishes. Even when students are physically present in the same place, there are situations where they prefer to communicate online rather than directly. This shift can lead to a decline in communication and social skills among students, which are essential for future professionals.

Information overload. This fact represents a serious problem in the modern "*information environment.*" We are surrounded by a multitude of information on everything and anything. The problem is no longer finding information; a much bigger problem is filtering and extracting reliable and accurate information. The widespread availability of the internet allows individuals to create websites, blogs, or social media pages containing unverified and often misleading content. Exposure to false information can lead to incorrect learning and create confusion among students.

Health consequences. The presence of technology in classrooms can lead to the creation of new or the increase of existing dependence on technological devices and the internet among students. The consequences of this dependence can manifest in various ways. It is well-known that spending too much time in front of screens and having poor ergonomic habits can cause problems with eyes, musculoskeletal systems, and many other issues.

Academic Dishonesty Problem. One of the most pressing concerns in contemporary education is the rise of academic dishonesty facilitated by AI tools. The fact is that an increasing number of students use AI tools to write their papers, complete assignments, and conduct research as part of their studies. Tools such as ChatGPT, Textero, and many others have become very popular and widely used by students in their work.

Additionally, *algorithmic bias* in GAI educational systems represents a significant ethical challenge. Research has demonstrated that this bias can primarily affect groups, reflecting collective societal prejudices embedded in the data. Consequently, AI tools may unjustifiably identify minority students as at-risk based on socioeconomic disadvantages [18]. This bias emerges when algorithms fail to account for diversity or when training data contains inherent prejudices. Educational institutions bear the

responsibility to implement rigorous strategies that detect and mitigate these issues.

The implementation of GAI in education raises significant concerns regarding *student data privacy* as these systems require extensive personal information to function effectively [19]. The proliferation of online learning platforms has introduced risks of unauthorized data access and misuse of sensitive information about students' learning patterns and personal characteristics. Educational institutions must establish comprehensive data governance frameworks that address the entire data lifecycle while ensuring compliance with relevant privacy regulations.

The use of GAI in education also creates complex *intellectual property challenges*, as uncertainty exists regarding who owns content created with these tools—the student, the institution, the developer, or potentially no one [20]. While authorities have indicated that works with significant human creative input may qualify for copyright protection, the boundary between human and machine contribution remains ambiguous. Educational institutions must establish clear policies addressing attribution, licensing, and fair use of GAI-generated materials, with particular emphasis on preserving students' rights to their creative work.

Berendt, Littlejohn, and Blakemore (2020) examine AI in education through the lens of fundamental human rights, emphasizing the need to balance technological benefits with potential risks to both students' and teachers' freedoms [21]. This perspective complements our discussion of algorithmic bias and privacy concerns, reinforcing the importance of ethical guidelines for GAI implementation in educational settings.

A growing concern among educators is whether AI-powered systems will eventually replace human teachers. Although this concern exists, it is unlikely that this will happen. First and foremost, these systems cannot replace the human relationship that a living teacher brings into the classroom, as well as their sense of classroom atmosphere. By classroom atmosphere, it means that a teacher can feel when students' concentration and work capacity start to decline and when it is necessary to intervene and motivate them. Similarly, a teacher can feel and see when students are more interested in a particular topic or subject and provide them with additional information or guide them to further sources of knowledge related to that topic.

It is also necessary to ensure that GAI systems are ethically responsible and transparent so that biases and discrimination are avoided in the classroom. However, a study conducted among teachers regarding their attitudes toward GAI showed that most of them (35%) are still uncertain about the application of GAI tools in the educational process (the results are shown in Fig. 1). In other words, they are neither for nor against. Furthermore, only 6% of teachers believe it is more useful than harmful, while 25% believe it is "*more harmful than useful*."
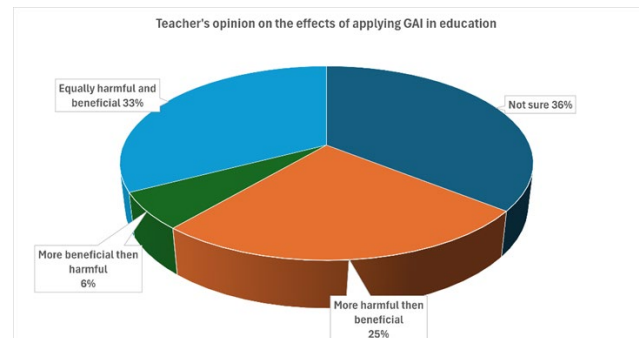

Figure 1. Teachers' opinions on the effects of GAI application in education

This comprehensive survey was conducted by Pew Research Center (2024) on a nationally representative sample of 2,563 K-12 teachers across diverse educational settings in the United States. The data was collected through a stratified random sampling approach between January and March 2024, with a response rate of 68% and a margin of error of +-2.1%. The survey methodology included a combination of online questionnaires and follow-up phone interviews to ensure data validity. The participants represented diverse demographics, teaching experience levels (ranging from 1 to 30+ years), and subject areas, providing a comprehensive view of educator perspectives on GAI technologies across different educational contexts [22].

These survey results reveal teachers' limited understanding of GAI technologies. This indicates the necessity of implementing comprehensive professional development programs that would enhance educators' digital literacy in this domain and adequately prepare them for the effective integration of these technological tools into their pedagogical practice.

5. Competencies for the application of GAI in education

Modern information technologies contribute to the enhancement and increased efficiency of the educational process [23]. With the emergence of AI and GAI, there is an inevitable need for new competencies for the effective use of these technologies. Undoubtedly, the leading competency that emerges as a necessity for working with these technologies is "Prompt Engineering". This discipline focuses on developing methods for formulating precise and effective queries to GAI systems to generate optimal results (content creation). It is a relatively new field whose significance has grown alongside the rapid development and increasing impact of AI and GAI systems on daily activities.

In addition to "Prompt Engineering" the use of GAI also requires competencies related to computer literacy, internet usage, and the application of modern AI technologies.

From a global perspective, all competencies necessary for the application of GAI in the educational process can be categorized into three levels as shown in Figure 2 [24]:

- *Basic competencies*: Fundamental skills required to work with GAI tools.
- *AI competencies*: Knowledge and skills necessary for using and working with new technologies, tools, and applications in the field of Artificial Intelligence.
- *Emergent competencies*: Newly developed competency that did not exist previously but has emerged as a result of using AI and GAI tools. These compentencies are distinctive for their dynamic nature and ability to adapt to emerging technological demands.

Although these three levels appear to be independent entities, all the competencies they encompass are closely interconnected and interdependent.

Basic (foundational) competencies represent prerequisites for the successful use of GAI tools in the educational process. From a teacher's perspective, most commonly include [24]:

- Knowledge and skills in using digital technologies for personal professional development, innovation, communication, etc.
- Knowledge and skills to create and share digital learning and teaching content.
- Knowledge and skills to use digital tools to improve their pedagogical work.
- Knowledge and skills to design reliable, valid, and transparent digital assessment tools.
- Knowledge and skills in fostering students' responsibility and encourage the development of their digital competencies.

AI-related competencies, typically, they refer to:

- *Algorithmic competencies* – The ability to apply algorithmic thinking, as well as understanding the basic structure and concepts of algorithms.
- *Programming competencies* – The ability to understand programming language concepts, write code, and represent real-life scenarios through code.
- *Data literacy* –The ability to analyse data in detail, identify patterns, and drawing conclusions.
- *AI competencies* – Understanding the basics of AI, how AI works with data, and how it uses data for learning and understanding the mechanisms behind AI technologies (machine learning, neural networks…), as well as understanding a wide range of AI tools and applications.
- *Ethical competencies* –The ability to address ethical concerns related to AI and GAI including issues of bias, fairness, accountability, discrimination, transparency, and intellectual property.
- *Social competencies* – Understanding how AI impacts daily life and human activities, assessing its positive

and negative effects on society, evaluating its ecological footprint, and developing critical skills for combating misinformation and fake content in the digital space…
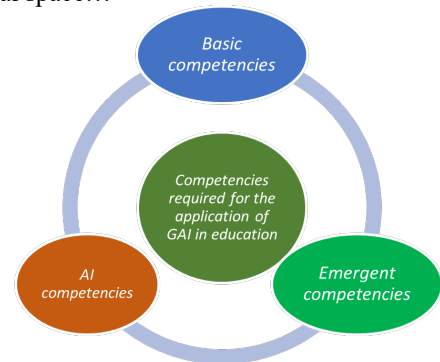

Figure 2. Types of competencies required for the successful application of GAI in education

When discussing the application of generative artificial intelligence (GAI) in the educational process, it requires not only the technical training of teachers for its use but also their continuous professional development and lifelong learning. The training process should focus on further developing teachers' digital competencies while also enhancing their pedagogical approaches through interactive teaching methods.

The organization of various seminars, workshops, and peer-learning programs allows teachers to exchange experiences and define strategies for the successful integration of GAI into the educational process. Special attention in these training sessions should be given to academic integrity, the ethical use of GAI, and methods for assessing students' work in the context of AI application. In this way, professional training would not only serve as technical upskilling but also as motivation for the professional and personal growth of teachers within the modern educational framework.

6. Future directions of research and development in the application of GAI in education

The unique features and capabilities of Generative AI (GAI), along with its diversity and adaptability, make it highly relevant subject for further research. However, teachers often express concerns and uncertainties regarding its use, particularly that GAI might eventually replace them in the educational process. This, however, will not happen.

What is certain is that the role and position of teachers in education will evolve. Educators will increasingly focus on aspect of direct student engagement (e.g., mentoring support, ethical guidance, etc.) in the teaching process, as well as other "*human*" elements that are "*impossible*" for GAI to perform. Because of this, teacher presence in the classroom remains essential, and they certainly cannot be

excluded from the educational process. Undoubtedly, GAI has a great potential for application in teaching in the near future, which is why further research and analysis of GAI in the context of its application in the educational process are necessary. This analysis points to several important directions for future research including following questions [25]:

- *Development of GAI-based educational models and frameworks* – Establishing innovative educational models that support both teachers and students while enhancing the effectiveness of teaching methodologies and learning outcomes. These models would also enable researchers to analyse their impact on the educational process in detail.

- *Assessing the impact of GAI-assisted learning on student performance and behavioural patterns* – The application of GAI in the learning process provides numerous possibilities for the potential misuse of these technologies by students. On the other hand, if properly channelled and used, it can have multiple benefits for students, fostering creativity, critical thinking, problem-solving skills, and the creation of works of art. Therefore, it is important to investigate this issue.

- *Exploring GAI-assisted learning across diverse student profiles* – Future studies could examine GAI's impact on students across different knowledge levels. Additionally, the impact of GAI-based learning can be examined in different fields such as art, design, mathematics, etc.

- *Reevaluating pedagogical theories with the application of GAI in education* – The use of GAI in education brings entirely new concepts and approaches to the teaching process. This paradigm shift creates the need to reconsider traditional pedagogical theories from a new perspective.

- *Developing effective GAI-driven instructional strategies* – While GAI offers advantages in terms of adaptive learning and content generation, it also presents challenges. Research should focus on identifying and implementing strategies that maximize student learning outcomes while mitigating drawbacks.

- *Defining various roles of GAI in education* – GAI can play different roles in the educational process (mentor, student, learning partner, etc.). By examining this segment, we can identify which role is most effective in specific situations and fields of application.

- *Establishing ethical guidelines for the use of GAI in education* – The application of GAI carries potential ethical issues and problems. Addressing this area would contribute to the formation of ethical guidelines that minimize the risks associated with GAI application from an ethical standpoint.

- *Investigating different forms of collaboration between GAI and humans* – GAI can play various roles, and it would be interesting to investigate how the relationship between humans and GAI changes with these role transitions.

- *Analysing the use of GAI-based multimedia applications in education* – With the development of GAI, the concepts of multimedia applications are evolving. It would be interesting to explore the effects of this process.

- *Exploring personalized learning trough GAI-powered adaptive systems* – It is advisable to consider and develop guidelines on how combining modelling and simulation tools based on Artificial Intelligence, such as GAI tools, can contribute to creating adaptive learning conditions tailored to each individual in the learning process.

- *Integrating "embodiment" functionalities through the connection of GAI with educational robots* – It is well known that the learning process involves not only cognitive actions but also physical activities and interactions with the environment. This allows for a richer and more natural learning experience as students are engaged not only intellectually but also physically, which requires deeper understanding and participation in the process. For example, an educational robot can be used to demonstrate a physical action, while GAI allows for the adaptation of this action based on the specific feedback from the student.

Schiff's analysis (2022) of national AI policy strategies reveals a concerning trend: while AI ethics are prominently discussed in policy documents, the ethical implications of AI in education receive minimal attention. Instead, education is primarily viewed as instrumental for developing an AI-ready workforce rather than as a domain for thoughtful AI implementation [26]. This insight supports our call for developing ethical guidelines and reconsidering pedagogical theories in light of GAI application in education.

Based on everything mentioned, we can summarize that future research must encompass a broad spectrum of topics related to the application of generative AI in education, such as ethical, pedagogical, and technological aspects (shown in Fig. 3). The innovations brought by generative AI will require constant adaptation of teaching processes due to the dynamics they introduce into the classroom.
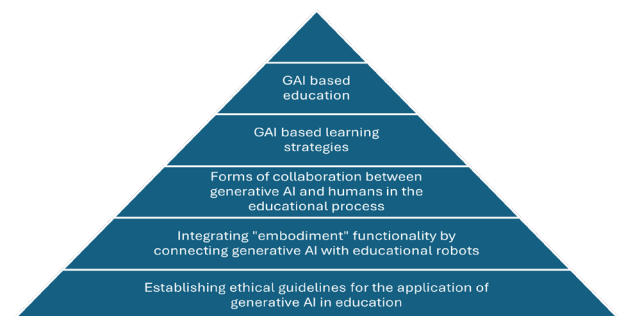
Figure 3. Summary of future research directions related to the application of generative AI in education

Innovative activities in educational institutions represent one of the most important strategic directions in education. This is a crucial issue for contemporary technologies across all areas of education, especially in technology training at higher education institutions that educate highly qualified professionals [27].

It is not an exaggeration to state that the development of new strategies for integrating generative AI in education, will lead to richer and more personalized learning experiences, ultimately enhancing student outcomes. For educators, as well as policymakers, it is of essential importance to gain a comprehensive understanding of the impact of these technologies on educational outcomes in order to mitigate risks and harness the advantages of artificial intelligence for the education system and sustainable development in general [28].

7. From Theory to Practice: Case Studies of Generative Artificial Intelligence Implementation in Education

The practical application of generative artificial intelligence within the educational process provides vital insights into the impact of these technologies on the learning and teaching process. A study conducted at universities in Hong Kong, which included 399 undergraduate and postgraduate students, demonstrated a positive attitude toward GAI technologies in the educational process [29]. Within this study, students specifically recognized and emphasized the potential of GAI for personalized learning support, indicating a significant advantage of GAI in adapting the learning process to students' individual needs compared to other traditional learning methods.

A notable example of GAI implementation in the educational process worth mentioning is the development of the virtual *co-tutor* **EDU**, which resulted from the collaboration between **EUDE Business School** (Escuela Europea de Dirección y Empresa) educational institution and **IBM** corporation [30]. The term ***co-tutor*** was deliberately used to emphasize the collaborative aspect and the fact that the system was designed as support or assistance to the main lecturer, rather than as an independent instructor. The system is based on IBM Watson Assistant and Watson Discovery technologies and provides students with real-time responses to logistical, administrative, and academic inquiries, significantly enhancing the student experience. Results from the pilot implementation demonstrated increased student engagement with this system present and faster response times to student requests and inquiries. Additionally, the system allowed teaching staff to focus on more complex educational tasks instead of routine administrative duties.

In the field of language learning, **Berlitz** (an internationally renowned language learning institution founded in 1878) successfully implemented Azure AI Speech technology in collaboration with Microsoft Corporation to enhance the language learning process [30].

The introduction of these technologies enabled student pronunciation assessment without the presence of an instructor. This attracted students and brought a large number of new enrolments to the institution. Furthermore, these technologies provided a significant reduction in operational costs and secured considerable financial benefits for the institution itself.

Another successful example of GAI application in education is **Bolton College**. This college utilized an AI platform in collaboration with Synthesia company to create educational video materials [30]. This approach eliminated the need for expensive production equipment such as cameras, editing studios, and more. Additionally, it enabled instructors without professional knowledge in this field to create high-quality educational materials.

Research conducted among students has also shown that they particularly value the ability to use GAI for homework assessment and finding solutions, which enables them to "*improve their depth of thinking and understanding*" [29].

All these examples (and there are many more) indicate that GAI is not merely a theoretical concept, but an applicable technology that is successfully being introduced and utilized in educational institutions worldwide. In its application, it brings benefits to both sides of the educational process—students and teachers. The case studies presented in this paper confirm the theoretical premises regarding GAI's potential in personalizing learning, automating administration, and creating interactive educational content tailored to learners' individual needs.

8. Conclusion

This paper has examined the multifaceted influence of GAI on the educational process. Through our analysis of theoretical concepts and practical implementations, we have established that GAI serves a foundation for transforming education by enabling personalized learning and improving the efficiency of the teaching process. The reviewed case studies from educational institutions worldwide demonstrate that GAI is not merely a theoretical concept but a practical technology being successfully adopted across diverse educational contexts.

The theoretical exploration reveals that GAI's capabilities extend beyond conventional education technologies, enabling adaptive leraning models where progress at their own pace while receiving continuous feedback. Our examination of competencies necessary for effective GAI implementation highlights the emergence of new skill requirements such as prompt engineering and algorithmic thinking, which are becoming increasingly essential in contemporary educational frameworks.

The practical case studies presented- from EUDE's virtual co-tutor to Berlitz's language learning tools- validate the theoretical potential of GAI by showing tangible improvements in student engagement, administrative efficiency and educational personalization. These implementations demonstrate how carefully

designed GAI systems can rather enhance than replace human educators, reinforcing our findings that the human factor remains crucial in education process.

Despite these opportunities, our analysis acknowledges significant challenges, including attention disruption, information overload potential weakening of social skills, and increased concerns regarding academic integrity. The responsible application of GAI in education demands ethical vigilance and transparency to prevent biases, discrimination, and negative pedagogical effects.

Looking forward, we identified promising research directions, including the incorporation of "*embodiment*" functionality through connecting GAI with educational robots, making educational process more interactive and dynamic. Future research should continue investigating how GAI can enhance personalized learning while ensuring ethical implementation.

With the advancement of new strategies, continued innovation, and responsible application, GAI has the potential to contribute to a more dynamic and efficient education system, ensuring high-quality learning outcomes and tailored support for each student in developing creativity, critical thinking, and personalized learning paths.

References

[1] Moshinski V, Pozniakovska N, Mikluha O, Voitko M. Modern education technologies: 21st century trends and challenges. In: Proceedings of the SHS Web of Conferences; 2021; Odesa, Ukraine. Les Ulis: EDP Sciences; 2021. doi.org/ 10.1051/shsconf/ 202110403009.

[2] Vygotsky LS. Mind in society: The development of higher psychological processes. Cambridge (MA): Harvard University Press; 1978.

[3] Wood D, Bruner JS, Ross G. The role of tutoring in problem solving. J Child Psychol Psychiatry. 1976;17(2):89-100.

[4] Sweller J, van Merriënboer JJG, Paas F. Cognitive architecture and instructional design: 20 years later. Educ Psychol Rev. 2019;31(2):261-292.

[5] Anderson LW, Krathwohl DR, editors. A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives. New York: Longman; 2001.

[6] Piaget J. The construction of reality in the child. New York: Basic Books; 1954

[7] Siemens G. Connectivism: A learning theory for the digital age. Int J Instruct Technol Distance Learn. 2005;2(1):3-10.

[8] Holmes W, Tuomi I. State of the art and practice in AI in education. European Journal of Education. 2022;57(4):542-570. doi:10.1111/ejed.12533

[9] Ji Z, Lee C, Han B, Wang R, McAuley J, Ma Y. Survey of hallucination in natural language generation [Internet]. arXiv; 2022 [cited 2025 May 7]. Available from: https://arxiv.org/abs/2202.03629

[10] Mojsilović M, Cvejić R, Pepić S, Karabašević D, Saračević M, Stanujkić D. Statistical evaluation of the achievements of professional students by combination of the random forest algorithm and the ANFIS method. Heliyon. [1] 2023 Nov;9(11):e21768. doi:10.1016/j.heliyon.2023.e21768

[11] Ngbargbara BP, Odibo A. Effect of Generative Artificial Intelligence (GAI) on Science Education Students' Achievements in Federal University Otuoke, Bayelsa State. FUO-Journal of Educational Research. 2024;3(2):121-131. doi:10.5281/zenodo.13825732.

[12] Usa today. What jobs are most exposed to AI? Usa today [Internet].; [cited 2024 Dec 5]. Available from: https://www.usatoday.com/story/money/2023/08/04/jobs-most-exposed-ai/70523057007/.

[13] Thurzo A, Strunga M, Urban R, Surovkova J, Afrashtehfar KI. Impact of Artificial Intelligence on Dental Education: A Review and Guide for Curriculum Update. Education Sciences. 2023;13(2):150. doi:10.3390/educsci13020150.

[14] Sun L, Zhou L. Does Generative Artificial Intelligence Improve the Academic Achievement of College Students? A Meta-Analysis. Journal of Educational Computing Research. [1] 2024;62(7):1896-1933.doi:10.1177 /073563312 41277937.

[15] Abu Saa A, Al-Emran M, Shaalan K. Factors Affecting Students' Performance in Higher Education: A Systematic Review of Predictive Data Mining Techniques. Tech Know Learn. 2019;24:567-598.doi:10.1007/s10758-019-09408-7.

[16] Generative Artificial Intelligence. Center for Teaching Innovation [Internet]. [cited 2024 Dec 22]. Available from: https://teaching.cornell.edu/generative-artificial-intelligence#HigherEd.

[17] The Impact of Technology on Education: Positive and Negative Effects. Futuramo blog [Internet]. 2024 Oct 16 [cited 2024 Dec 16]. Available from: https://futuramo.com/blog/the-impact-of-technology-on-education-positive-and-negative-effects/.

[18] FairAIED. Navigating Fairness, Bias, and Ethics in Educational AI Applications [Internet]. arXiv; 2024 [cited 2025 May 4]. Available from: https://arxiv.org/html/2407.18745v1

[19] Huang L. Ethics of Artificial Intelligence in Education: Student Privacy and Data Protection [Internet]. ResearchGate; 2023 Jun 30 [cited 2025 May 4]. Available from: https://www.researchgate.net/publication/372125102_Ethics_of_Artificial_Intelligence_in_Education_Student_Privacy_and_Data_Protection

[20] IP & Technology Law Society. AI, Copyright, and the Law: The Ongoing Battle Over Intellectual Property Rights [Internet]. 2025 Feb 4 [cited 2025 May 5]. Available from: https://sites.usc.edu/iptls/2025/02/04/ai-copyright-and-the-law-the-ongoing-battle-over-intellectual-property-rights/

[21] Berendt B, Littlejohn A, Blakemore M. AI in education: learner choice and fundamental rights. Learning, Media and Technology. 2020 ; 45(3) :312-324. doi:10.1080/17439884.2020.1786399

[22] Pew Research Center. A quarter of U.S. teachers say AI tools do more harm than good in K-12 education [Internet]. 2024 May 15 [cited 2024 Dec 10]. Available from: https://www.pewresearch.org/short-reads/2024/05/15/a-quarter-of-u-s-teachers-say-ai-tools-do-more-harm-than-good-in-k-12-education/sr_24-05-15_ai-in-class_1/.

[23] Mykolaiko V, Honcharuk V, Gudmanian A, Kharkova Y, Kovalenko S, Byedakova S. Modern problems and prospects of distance educational technologies. International Journal of Computer Science & Network Security. 2022;22(9):300-306. doi:10.22937 /IJCSNS.202 2.22.9.40.

[24] Sattelmaier L, Pawlowski J. Towards A Generative Artificial Intelligence Competence Framework for Schools. 2023. doi:10.2991/978-94-6463-340-5_26.

[25] Hwang G-J, Chen N-S. Editorial Position Paper: Exploring the Potential of Generative Artificial Intelligence in

Education: Applications, Challenges, and Future Research Directions. Educational Technology & Society. 2023;26(2). doi:10.30191/ETS.202304_26(2).0014.

[26] Schiff D. Education for AI, not AI for Education: The Role of Education and Ethics in National AI Policy Strategies. Int J Artif Intell Educ. 2022;32(3):527-563. doi:10.1007/s40593-021-00270-2

[27] Kakhkhorov KS, Rasulova DZ. Methodology of improving the professional activity of the future teacher of technology on the basis of modern educational technologies. Universal J. of Educational Research. 2020;8(12):7006-7014. doi:10.13189/ujer.2020.081268.

[28] Alshamsi I, Sadrivala FK, Alazzawi IF, Shannaq B. Exploring the impact of generative AI technologies on education: Academic expert perspectives, trends, and implications for sustainable development goals. Journal of Infrastructure, Policy and Development. 2024;8(11):8532. doi:10.24294/jipd.v8i11.8532.

[29] Zhang C, Du J, Wang Y, Kuang X, Tsang KK, Kwong T, et al. Students' voices on generative AI: Perceptions, benefits, and challenges in higher education. Int J Educ Technol High Educ. 2023;20(1):80. https://doi.org/10.1186/s41239-023-00411-8

[30] VKTR. 5 AI case studies in education [Internet]. 2024 Mar 14 [cited 2025 May 2]. Available from: https://www.vktr.com/ai-disruption/5-ai-case-studies-in-education