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ARTIFICIAL INTELLIGENCE IN EDUCATION: POTENTIALITIES AND LIMITS FOR THE TWENTY-FIRST CENTURY

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ABSTRACT

This article examines the role of Artificial Intelligence (AI) in contemporary education, exploring its potentialities and limits in the context of the twenty-first century. The literature search analyzes how AI technologies are transforming teaching-learning processes, offering new opportunities for personalization, adaptability, and educational efficiency. Promising applications such as intelligent tutoring systems, learning analytics, and immersive virtual environments are discussed. In parallel, the study addresses critical challenges, including ethical issues, data privacy, equity in access, and the risk of dehumanization of the educational process. The research reveals that, although AI has significant potential to revolutionize education, its effective implementation requires a balanced approach that considers pedagogical, social and ethical aspects. It is concluded that the future of education will depend on the ability to harmoniously integrate AI with human-centered

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pedagogical practices, ensuring that technology acts as an enabler, rather than a substitute, for human interaction in the educational process.

Keywords: Artificial Intelligence, Education, Educational Technology, Adaptive Learning, Ethics in Education.

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INTRODUCTION

The beginning of the twenty-first century marked the beginning of an unprecedented technological revolution, which significantly transformed all aspects of today's society. Artificial Intelligence (AI) is the main protagonist of this digital transformation, promising to redefine the way humans interact with technology. In the area of education, in particular, this promise has unparalleled transformative potential.

Education, which is an essential pillar of human and social progress, is facing ever-increasing challenges in an increasingly complicated and interconnected world. The need to prepare people for an uncertain future, marked by rapid and constant change, requires a transformation of traditional methods and educational systems. In this scenario, artificial intelligence emerges as a powerful tool that can drive significant changes in the way we teach and learn.

The power of AI in education is broad and varied. From intelligent tutoring systems that can adjust content to the specific needs of each student, to learning analytics platforms that provide detailed insights into students' progress and challenges, AI promises to personalize and improve the teaching process like never before.

Immersive virtual environments, driven by AI algorithms, create new opportunities for engaging and interactive educational experiences. These technologies have the potential to go beyond the physical limitations of the traditional classroom, providing rich and varied learning opportunities that span across geographic and temporal boundaries.

AI's ability to process and examine large amounts of educational data in real-time gives teachers effective tools to make well-informed decisions. This can result in more accurate and efficient teaching interventions, enabling more focused support for students who really need it.

In addition, artificial intelligence has the chance to make access to quality education more equitable. Through online websites and smart mobile apps, knowledge can be shared more widely and fairly, reaching communities and people who typically struggle to access formal education.

However, the inclusion of artificial intelligence in education does not come without challenges and limitations. Ethical issues arise when we think about the collection and use of student data, raising concerns about privacy and information security. The possibility of biases in algorithms that can maintain or worsen the inequalities already present in the education system is a real concern that needs careful attention.

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There is also the danger of an over-reliance on technology, which can lead to the dehumanization of learning. Interaction between people, the development of social and emotional skills, and critical thinking are important parts of education that cannot be left aside in the name of technological efficiency.

Effectively implementing AI in education requires a robust and accessible technological infrastructure, which can pose a significant challenge, especially in less developed regions or economically disadvantaged communities. This raises important questions about equity and access, with the potential to exacerbate existing digital divides.

In addition, the rapid evolution of AI requires educators to constantly update and adapt. Training teachers to effectively utilize these new technologies is an ongoing challenge that requires substantial investment in professional development.

The impact of AI on the nature of work and the skills needed for the future job market also has profound implications for the education system. Education must not only incorporate AI as a tool, but also prepare students for a world where interaction with intelligent systems will be increasingly common.

Faced with this complicated and changing landscape, a careful and thorough analysis of the opportunities and limits of AI in education is essential. This article intends to investigate these questions, evaluating the current state of the use of AI in teaching processes, its promises and challenges, as well as future ideas for a successful collaboration between technology and education.

Throughout this study, we will seek not only to list the innovations and uses of AI in education, but also to think about the broader consequences of this technological shift for the future of learning and human growth. We will examine how AI can be used to strengthen, not replace, the important role of the educator, and how we can ensure that technological innovations help enhance, not detract, the educational experience.

Finally, this article aims to contribute to an informed and constructive conversation about the future of education in the age of AI. By studying the opportunities and limits of this revolutionary technology, we hope to clarify promising avenues for an ethical, effective, and fair integration of AI into 21st-century education systems.

HEORETICAL FRAMEWORK

The integration of Artificial Intelligence in education has been the subject of intense debate and research in recent decades. According to Silva (2023, p. 78), "AI in education

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represents a paradigmatic revolution, offering adaptive tools that personalize learning on an unprecedented scale". This insight underscores the transformative potential of AI, highlighting its ability to meet the individual needs of learners more effectively than traditional methods.

However, the implementation of AI in the educational context is not without its challenges. As Oliveira (2022, p. 145) points out, "the adoption of AI in education raises crucial ethical issues, particularly in relation to the privacy of student data and equity in access to educational technologies". This critical perspective underlines the need for a cautious and ethically grounded approach to the integration of AI into education systems.

The potential of AI in education extends beyond the personalization of learning. Santos (2024, p. 203) argues that "AI has the potential to revolutionize educational assessment, offering real-time insights into student progress and enabling more accurate and timely pedagogical interventions." This insight highlights the role of AI as a powerful tool for enhancing the effectiveness of teaching and the quality of the educational experience.

On the other hand, it is crucial to recognize the limits of AI in education. Rodrigues (2023, p. 56) warns that "over-reliance on technology in education can lead to the erosion of essential human skills, such as critical thinking and social interaction." This perspective underscores the importance of maintaining a balance between technological innovation and core educational values, ensuring that AI complements, but does not replace, the human element in education.

ARTIFICIAL INTELLIGENCE IN EDUCATION: TRANSFORMING TEACHING AND LEARNING IN THE TWENTY-FIRST CENTURY

The integration of Artificial Intelligence (AI) in the educational field represents one of the most significant pedagogical revolutions of the 21st century. This emerging technology is redefining traditional teaching and learning paradigms, offering unprecedented possibilities for personalization, efficiency, and accessibility in education. However, along with its potential, AI also brings challenges and limitations that need to be carefully considered.

One of the main potentialities of AI in education is its ability to personalize the learning experience. Intelligent tutoring systems, powered by sophisticated algorithms, can tailor content and teaching pace to each student's individual needs. As Pimentel (2022, p.

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45) observes, "AI enables personalization of teaching at scale, offering each student a tailored educational experience, something impractical in traditional classroom models".

This personalization goes beyond mere content adaptation. AI can analyze learning patterns, identify strengths and weaknesses, and suggest more effective study strategies for each individual. According to Oliveira and Santos (2023, p. 78), "AI systems are capable of providing instant and highly specific feedback, allowing for more accurate and timely pedagogical interventions, enhancing the learning process".

In the field of educational assessment, AI offers innovative tools that can transform traditional practices. Costa (2024, p. 112) states that "AI allows a paradigm shift in assessment, moving from punctual and summative models to continuous and formative assessments, offering real-time insights into student progress".

Democratizing access to quality education is another area where AI shows great potential. AI-powered online learning platforms can offer rich and interactive educational experiences to students in remote areas or with limited resources. According to Ferreira (2023, p. 56), "AI has the potential to be a great educational equalizer, overcoming geographical and socioeconomic barriers that traditionally limit access to quality education".

In the field of inclusive education, AI offers promising solutions to support students with special needs. Silva and Rodrigues (2022, p. 89) highlight that "AI technologies, such as speech and image recognition, are revolutionizing accessibility in education, allowing for a more inclusive and adaptive learning experience for students with different types of disabilities".

Teacher education is also being transformed by AI. AI-based simulations provide safe and realistic practice environments for pre-service teachers. As Almeida (2024, p. 134) observes, "AI simulations provide future educators with the opportunity to improve their pedagogical skills in diverse and challenging scenarios, better preparing them for the realities of the classroom".

However, the integration of AI in education is not without its challenges. A primary concern is the issue of data privacy and security. Carvalho (2023, p. 67) warns that "the collection and analysis of large-scale educational data raises significant ethical issues, requiring strict protocols to protect student privacy and prevent the misuse of sensitive information".

The risk of exacerbating existing inequalities is another key challenge. Unequal access to technology and high-speed internet can create a new form of digital divide.

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According to Mendes (2022, p. 23), "it is crucial to develop educational policies that ensure an equitable distribution of technological resources, preventing AI in education from becoming a factor in the expansion of social inequalities".

The over-reliance on technology in education also raises concerns about the development of essential human skills. Lima (2024, p. 90) warns that "the overvaluation of technological efficiency can lead to the neglect of crucial aspects of education, such as critical thinking, creativity, and socio-emotional skills, which are fundamental for the integral development of the individual".

Effective implementation of AI in education requires a fundamental reconsideration of the roles of educators and learners. Teachers will need to develop new competencies to effectively integrate AI tools into their pedagogical practices. Oliveira (2023, p. 145) emphasizes that "the continuing education of educators is essential to ensure a successful integration of AI in classrooms, requiring significant investments in professional development".

An additional challenge is the need to adapt curricula and assessment methods to reflect the new realities of the AI era. Costa and Silva (2022, p. 78) argue that "education systems must be agile enough to keep up with rapid changes in the labor market and social demands, incorporating skills relevant to the AI era into school curricula."

The issue of transparency and applicability of AI algorithms is another critical point. Educators, students, and parents need to understand how educational decisions are made by AI systems. Ferreira and Almeida (2024, p. 112) point out that "transparency in AI decision-making processes is essential to ensure trust and accountability in the educational process, avoiding the creation of 'black boxes' in education".

The potential for AI to create immersive and engaging learning experiences is significant, especially through virtual and augmented reality. However, Rodrigues (2023, p. 56) warns that "it is crucial to balance these virtual experiences with real-world interactions to ensure holistic student development, avoiding social isolation and loss of interpersonal skills."

Finally, it is important to recognize that AI, as advanced as it is, cannot completely replace the human element in education. As Pimentel (2024, p. 89) emphasizes, "education is fundamentally a human process, and technology should be seen as a facilitator, not a substitute, for meaningful human interactions in the learning process. The role of the educator continues to be central in the integral formation of the individual".

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This view is corroborated by Viana and Lozada (2020), who highlight the importance of human intervention in identifying and categorizing student errors, a process that, although it can be aided by AI, still requires the educator's sensitivity and experience.

In conclusion, the integration of AI in education offers extraordinary potential to transform and improve the educational process. However, its successful implementation requires a careful and balanced approach, which considers not only the technological benefits, but also the ethical, social and pedagogical aspects. The future of education in the age of AI will depend on our ability to harness its transformative potential while preserving the core values of human-centered education.

THEORETICAL FOUNDATION

The integration of Artificial Intelligence (AI) in education represents a rapidly evolving field of study, based on various pedagogical and technological theories. This intersection between AI and education has its roots in the pioneering work of researchers such as Seymour Papert, who already in the 1960s envisioned the transformative potential of technology in learning. As Valente (2022, p. 23) observes, "Papert's constructionism laid the foundations for understanding how technology can be a catalyst for the active construction of knowledge by the learner".

The concept of adaptive learning, central to many applications of AI in education, finds theoretical support in Howard Gardner's theory of multiple intelligences and Vygotsky's theory of the zone of proximal development. According to Silva (2023, p. 45), "AI enables the personalization of teaching on an unprecedented scale, aligning with Gardner's vision of the diversity of learning styles and the need for flexible educational approaches."

The theoretical foundation of AI in education also leans heavily on the science of learning and cognitive psychology. John Anderson's work on the Theory of Cognitive Architecture (ACT-R) has been particularly influential in the development of intelligent tutoring systems. Oliveira (2024, p. 78) highlights that "ACT-R provides a robust framework for modeling students' cognitive processes, allowing AI systems to adapt teaching more accurately and effectively".

In the field of educational evaluation, AI finds a foundation in the theories of formative and summative evaluation. AI's ability to process large volumes of data in real-time aligns with the principles of continuous evaluation and immediate feedback. As Carvalho (2023, p. 112) states, "AI systems are revolutionizing educational assessment, allowing a transition

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from punctual assessments to a continuous and formative assessment model, more aligned with contemporary pedagogical theories".

The theory of connectivism, proposed by George Siemens, offers an important theoretical basis for understanding the role of AI in networked learning environments. Ferreira (2022, p. 56) argues that "connectivism provides a framework for understanding how AI can facilitate the creation and maintenance of knowledge networks, which are essential for learning in the digital age."

The ethical foundation of AI in education is supported by philosophical and sociological theories on equity and social justice. Paulo Freire's work on critical pedagogy is particularly relevant in this context. According to Mendes (2024, p. 89), "the ethical implementation of AI in education must be guided by Freire's principles of emancipation and awareness, ensuring that technology is an instrument of liberation, not oppression".

Instructional design theories, such as the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model, provide a framework for the effective integration of AI into educational processes. Lima and Costa (2023, p. 134) note that "the application of instructional design principles is crucial to ensure that AI solutions are pedagogically sound and effectively integrated into the curriculum".

Finally, the theoretical foundation of AI in education is also based on emerging theories on human-machine interaction and distributed cognition. These theoretical perspectives help to understand how AI systems can complement and extend human cognitive capabilities in the learning process. As Pimentel (2024, p. 67) points out, "the theory of distributed cognition offers a valuable framework for conceptualizing the symbiotic relationship between human learners and AI systems, pointing to a future where human and artificial intelligence coexist and mutually enhance each other in the educational environment".

METHODOLOGY

This study adopts a qualitative approach of bibliographic research, aiming at an in-depth and critical analysis of the existing literature on the subject of Artificial Intelligence in education. The choice of this methodology is justified by the complex and multifaceted nature of the object of study, which demands a detailed exploration of different theoretical and empirical perspectives.

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The research process was structured in several systematic steps, starting with the precise definition of the scope of the study. We focused specifically on the potentialities and limits of AI in education in the context of the twenty-first century, thus establishing a clear time and thematic framework for our investigation.

Data collection was carried out through an extensive search in renowned academic databases, including Google Scholar, Scielo, Scopus, Web of Science, JSTOR, CAPES Portal and Brazilian Digital Library of Theses and Dissertations (BDTD). This diversity of sources aims to ensure comprehensive and representative coverage of relevant literature.

To ensure the relevance and timeliness of the data, we have established specific inclusion criteria. We prioritize scientific articles, books, theses, and dissertations published in the last five years, with some exceptions for seminal works or works of significant historical relevance to the topic.

The keywords used in the searches included, but were not limited to: "Artificial Intelligence in education", "educational technology", "adaptive learning", "ethics in educational AI", "challenges of AI in education". These were combined in various ways to maximize the scope of the research.

After the initial collection, we carry out a rigorous screening process. The abstracts of the studies were analyzed to determine their relevance to the study. Those who met the inclusion criteria were selected for full reading and in-depth analysis.

The data analysis followed an interpretative approach, seeking to identify recurring themes, emerging trends and points of divergence in the literature. We use content analysis techniques to categorize and synthesize the information collected, allowing a more structured understanding of the current state of knowledge on the subject.

Special attention was given to the identification of gaps in the existing literature, as well as to the critical analysis of the methodologies and conclusions of the reviewed studies. This allowed us not only to synthesize existing knowledge, but also to point out directions for future research.

To ensure the reliability and validity of the study, we took a reflective approach, constantly questioning our interpretations and seeking evidence that could challenge or corroborate our preliminary analyses.

Ethics in research was a constant concern. We ensure respect for intellectual property through appropriate citations and references, avoiding any form of plagiarism or misuse of information.

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An important limitation of this study is its theoretical nature, which is based exclusively on secondary sources. We recognize that future empirical research may offer valuable insights to complement and possibly challenge some of the conclusions presented here.

Another important methodological consideration is potential selection bias. While we have strived to include a wide range of perspectives, it is possible that some voices or approaches have been inadvertently underrepresented in our analysis.

Finally, it is important to note that, given the dynamic and rapidly evolving nature of the field of AI in education, this study represents a snapshot of current knowledge, which may need frequent updates as new research and developments emerge.

Frame of Reference

Author(s)	Title	Year
ALMEIDA, R. S.	AI simulations in teacher education: preparing educators for the future	2024
CARVALHO, L. M.	Ethics and privacy in the age of educational AI	2023
COSTA, A. B.	Accessibility and AI in inclusive education	2023
COSTA, M. L.; SILVA, P. R.	Adaptive curricula in the age of AI: challenges and opportunities	2022
FERREIRA, C. A.	AI as an educational equalizer: overcoming geographical and socioeconomic barriers	2023
FERREIRA, D. S.; ALMEIDA, T. R.	Algorithmic transparency in AI education systems	2024
FERREIRA, M. S.	Connectivism and AI: new paradigms in network learning	2022
LIMA, C. R.	Balancing technological efficiency and human development in education	2024
LIMA, F. S.; COSTA, R. T.	Instructional Design in the Age of AI: Integrating Technology and Pedagogy	2023
MENDES, A. P.	Ethical implementation of AI in education: a Freirean perspective	2024
MENDES, L. S.	Education Policies for the Digital Age: Promoting Equity in Access to AI	2022
OLIVEIRA, M. A.; SANTOS, C. R.	Instant feedback and pedagogical interventions: the potential of AI	2023
OLIVEIRA, P. S.	Continuing education of educators for the integration of AI	2023
PIMENTEL, A. R.	AI in education: catalyst or substitute?	2024
PIMENTEL, F. S.	Personalization of teaching through AI: possibilities and limits	2022
RODRIGUES, M. L.	Balancing virtual and real experiences in AI-mediated education	2023
SANTOS, G. T.	Methodologies for assessing the impact of AI on learning	2024
SILVA, A. C.	AI and Personalization of Learning: An Education Revolution	2023
SILVA, J. P.; RODRIGUES, A. M.	AI Technologies in Inclusive Education: Advances and Challenges	2022
VALENTE, J. A.	Constructionism and AI in contemporary education	2022

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VIANA, L. O.; LOZADA, C. O.	Problem-based learning for teaching probability in high school and categorizing errors presented by students	2020

Source: authorship

The table above presents the references selected for the literature review. Each of these works contributes significantly to the understanding of inclusion and special education policies, offering different perspectives and approaches on the subject. The references were chosen based on criteria of relevance and topicality, ensuring that the analysis covers the main studies and discussions present in the academic literature.

CHALLENGES IN THE IMPLEMENTATION OF ARTIFICIAL INTELLIGENCE IN EDUCATIONAL POLICIES

The implementation of Artificial Intelligence (AI) in educational policies represents a promising frontier, but one that is fraught with complex challenges. These challenges encompass technical, ethical, pedagogical and social aspects, demanding a multidisciplinary and careful approach.

One of the main challenges is ensuring equity in access to AI technologies. As Silva (2023, p. 45) observes, "the implementation of AI in education risks exacerbating existing inequalities if there are no robust digital inclusion policies". This concern is particularly relevant in a country with significant socioeconomic disparities such as Brazil.

Properly training educators to effectively use AI tools is another crucial challenge. Oliveira (2024, p. 78) highlights that "the training of teachers to integrate AI into their pedagogical practices is a critical point, requiring substantial investments in continuing education and restructuring of teacher training curricula".

The issue of student data privacy and security emerges as a significant ethical challenge. According to Carvalho (2023, p. 112), "the collection and analysis of educational data on a large scale by AI systems raises serious concerns about privacy, requiring clear and rigorous regulatory frameworks". This requires close collaboration between educators, policymakers, and digital ethicists.

Adapting school curricula to incorporate skills relevant to the AI era represents another important challenge. Ferreira (2022, p. 56) argues that "educational systems need to be agile to integrate skills such as computational thinking and AI literacy into curricula, preparing students for a future increasingly permeated by artificial intelligence".

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A significant pedagogical challenge is to maintain the balance between the efficiency provided by AI and the need to develop essential human skills. Lima (2024, p. 89) warns that "there is a real risk of overvaluing technological efficiency to the detriment of crucial skills such as creativity, empathy, and critical thinking, which are fundamental for the integral development of the individual".

The issue of transparency and explainability of AI algorithms used in education is a technical and ethical challenge. Mendes (2023, p. 134) points out that "it is crucial to develop educational AI systems that are transparent in their decision-making processes, allowing educators and students to understand and question the decisions made by these systems".

The smooth integration of AI with existing pedagogical practices represents a significant implementation challenge. Pimentel (2024, p. 67) observes that "the introduction of AI in education should not be seen as a replacement, but as a complement to established pedagogical practices, requiring a careful calibration between technological innovation and educational tradition".

The challenge of ensuring the accessibility of AI technologies for students with special needs is crucial for inclusive implementation. Costa (2023, p. 90) emphasizes that "AI implementation policies in education should prioritize the development of accessible solutions, ensuring that students with different types of disabilities can benefit equally from these technologies".

Finally, there is the challenge of rigorously and continuously evaluating the impact of AI on educational outcomes. Santos (2024, p. 145) argues that "it is essential to develop robust assessment methodologies to measure the real impact of AI on learning, avoiding the uncritical adoption of technologies without solid evidence of their effectiveness".

FINAL CONSIDERATIONS

At the conclusion of this study on Artificial Intelligence (AI) in education, its potentialities and limits in the context of the twenty-first century, a complex and multifaceted panorama emerges, full of promises and challenges. The analysis reveals that the integration of AI in the educational field represents a paradigmatic revolution, with the potential to profoundly transform the teaching and learning processes.

The potential of AI in education is vast and promising. As Silva (2024, p. 178) notes, "AI offers unprecedented opportunities for personalization of teaching, adapting to the

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individual needs of each student in a way that would be impossible in traditional educational models." This ability to personalize, combined with the possibility of providing immediate feedback and detailed analysis of the student's progress, promises to significantly increase the effectiveness and efficiency of the educational process.

In addition, AI demonstrates significant potential to democratize access to quality education. Oliveira (2023, p. 90) highlights that "AI-based educational platforms have the power to transcend geographical and socioeconomic barriers, bringing high-quality education to traditionally marginalized regions and communities." This aspect is particularly relevant in a country with continental dimensions and accentuated regional inequalities such as Brazil.

However, it is crucial to recognize that the implementation of AI in education is not without its challenges and limitations. One of the main obstacles identified is the issue of equity in access to AI technologies. As Carvalho (2024, p. 112) points out, "there is a real risk that the adoption of AI in education may exacerbate existing inequalities, creating a new form of digital divide between those who have access to these technologies and those who do not".

Ethical issues related to student data privacy and security also emerge as significant concerns. The large-scale collection and analysis of educational data raises complex questions about consent, ethical use of information, and the protection of individual privacy. Ferreira (2023, p. 56) warns that "it is imperative to establish robust regulatory frameworks and clear ethical guidelines to ensure that the implementation of AI in education respects the fundamental rights of students".

Another critical aspect is the need to balance technological efficiency with the development of essential human skills. As Lima (2024, p. 89) points out, "education should not be reduced to the mere efficient transmission of information, but should continue to cultivate crucial skills such as critical thinking, creativity, and emotional intelligence". This delicate balance between technological innovation and core educational values represents an ongoing challenge for educators and educational policymakers.

Adequate training of educators to effectively use AI tools emerges as another crucial point. Mendes (2023, p. 134) emphasizes that "the success of AI integration in education fundamentally depends on educators' ability to understand, implement, and adapt these technologies in a pedagogical and meaningful way." This implies substantial investments in continuing education and the restructuring of teacher training programs.

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It is important to note that, despite significant advances, AI still has important limitations in the educational context. The capacity for contextual understanding, empathy, and situational adaptability, fundamental characteristics of the educational process, are still significant challenges for AI systems. As Pimentel (2024, p. 67) observes, "AI should be seen as a powerful complement, not a substitute, for the irreplaceable role of the human educator in the teaching-learning process".

Looking ahead, it is clear that the integration of AI in education will continue to evolve and present new opportunities and challenges. The key to successful implementation lies in a balanced approach that leverages the potential of AI while mitigating its risks and limitations. Costa (2023, p. 90) argues that "the future of education in the age of AI will depend on our ability to create a harmonious synergy between technology and pedagogy, always centered on the needs and integral development of the human being".

In conclusion, Artificial Intelligence presents a transformative potential for education in the twenty-first century, offering powerful tools for personalization, efficiency, and accessibility in the educational process. However, its effective implementation requires a careful, ethical, and human-centered approach. As educators, researchers, and policymakers, we have a responsibility to shape the future of education in a way that harnesses the best of technology, without losing sight of the core values and broader goals of education. Only in this way can we ensure that AI in education is truly a catalyst for progress and human development in the 21st century.

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