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The impact of augmented reality and artificial intelligence on pedagogical practices: theoretical foundations and methodological approach

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Abstract

This article is part of a doctoral research project exploring the integration of Artificial Intelligence (AI) and Augmented Reality (AR) for the personalization of learning. The main objective is to examine how these emerging technologies can transform pedagogical practices by adapting content, methods and pacing to the specific needs of each learner. This work also aims to design a digital educational environment combining AI and AR, capable of offering immersive learning experiences and personalization based on individual learning styles. This article presents the theoretical foundations of this research, the objectives pursued and an initial methodological approach to developing and evaluating this innovative framework.

Keywords: Augmented reality; Artificial Intelligence; Immersive learning; personalized learning

1. Introduction

1.1 Context and issues

In a world where the diversity of learner profiles continues to grow, education faces a major challenge: meeting the specific needs of each individual while maintaining an engaging and effective learning experience. Faced with these challenges, emerging technologies, notably Artificial Intelligence (AI) and Augmented Reality (AR), offer promising solutions for personalizing learning [1]. The aim is to move beyond traditional, often uniform teaching methods, to offer each learner a course tailored to his or her needs, pace and preferences [2]. However, despite the rise of these technologies, their combined integration into educational environments remains largely under-exploited [3]. While Artificial Intelligence (AI) enables real-time analysis of learners' performance and adaptation of content to their specific needs [4], Augmented Reality (AR), meanwhile, creates immersive environments that facilitate experiential learning and active engagement [5]. However, these two technologies have often been explored independently, limiting their combined potential. These two technologies are still often used separately, without any real synergy .This raises the question: How can we structure the integration of artificial intelligence (AI) and augmented reality (AR) technologies to overcome the limitations of traditional educational methods and offer a personalized, immersive learning experience tailored to individual learning styles, in order to optimize both learner engagement and pedagogical effectiveness?

Following on from this problematic, several hypotheses can be formulated to explore the impact of integrating augmented reality (AR) and artificial intelligence (AI) technologies into the learning process. These hypotheses aim to verify the effectiveness of these technologies in enhancing learner engagement, personalizing learning paths and

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maximizing pedagogical effectiveness, while overcoming the limitations of traditional approaches. Thus, we postulate that:

- Using AR for experiential learning will promote increased engagement and understanding of complex concepts.
- Integrating AI will enable pedagogical paths to be personalized to individual needs, optimizing learning outcomes.
- The combination of AR and AI will offer an adaptive environment, enhancing pedagogical effectiveness.
- Learners using a combined AI and AR system will have superior academic results and a better knowledge retention rate than those using traditional methods.

These hypotheses guide our approach and direct the following specific objectives:

- Assess the impact of AR on learner engagement.
- Analyze how AI can adapt pedagogical content to individual needs.
- Propose a technological framework integrating AR and AI for immersive pedagogical experiences.
- Analyze the effect of this combined AI and AR system on information retention and academic performance.

2. Expected contribution

These objectives and hypotheses will guide the development of an innovative educational solution, showing how the integration of AI and AR technologies can transform education, not only adapting to individual learning styles, but also offering an immersive and engaging experience. This research will pave the way for inclusive, optimized pedagogy based on emerging technologies.

This table summarizes the contributions, providing a clear and organized view of how the research affects pedagogy, practical applications, technology, and society.

Table1 Key contributions of research on the integration of AI and AR in education

Category	Key contribution	Details
Theoretical Contribution	Reflections on a New Pedagogy	Redefining Personalization: Proposes a framework for data-driven pedagogy using AI to analyze learners' needs and preferences. Impact of Immersion: Explores how AR-based immersive environments enhance motivation, retention, and engagement. Fostering Inclusion: Demonstrates how technology addresses diverse learner profiles.
Practical Contribution	Development of Concrete Educational Solutions	Hybrid AI-AR Solution: Combines AI for identifying learning styles and AR for creating interactive, immersive learning environments. Improved Teaching Tools: Tools to identify weak points, adjust teaching approaches, and offer contextually adapted solutions.
Technological Contribution	AI-AR Integration	Technological Architecture: Develops a platform combining machine learning for data analysis with adaptive AR environments. Standardized Practices: Defines best practices for implementing AI-AR in diverse educational contexts.
Societal Contribution	Towards Inclusive and Engaging Education	Inclusive Pedagogy: Demonstrates how AI and AR reduce inequalities by catering to diverse learner needs. Learner Engagement: Makes learning more engaging and reduces school dropouts. Educational Shift: Encourages rethinking curricula and teaching methods for the digital era.

In the following sections, we clarify the various concepts on which this research will be based.

3. Literature review

3.1. Education and Augmented Reality

Augmented reality (AR) is a technology that superimposes digital elements (images, sounds, information) onto the actual view of a physical environment, usually via devices such as smartphones, tablets or special glasses. Unlike virtual reality (VR), which creates a fully immersive, simulated environment, AR enriches the real world by adding virtual objects or information, while allowing the user to perceive the physical environment around them [6].

AR offers many pedagogical potentialities that can transform traditional learning and enable a more interactive and immersive experience:

- Increased engagement and interaction: AR makes learning more engaging by allowing students to visualize abstract or complex concepts in real-life contexts, creating more interactive and motivating learning experiences [7].
- Experiential learning: thanks to AR, learners can interact with simulations in real time, enabling them to manipulate objects or have hands-on experiences, even without complex physical hardware. This type of experiential learning is particularly useful in scientific disciplines, medicine or history [8].
- Contextualization and personalization: AR makes it possible to link academic information to real-life contexts. For example, learners can explore geographical information by overlaying data on physical maps. This contextualization helps students understand the link between theory and practice. What's more, it can be used to personalize learning by tailoring educational resources to the specific needs of the student [9].
- Fostering collaborative learning: AR facilitates collaborative learning activities where students can interact not only with digital elements, but also with each other. This promotes cooperation and knowledge exchange in an enriched environment [10].
- Accessibility and inclusion: AR can be used to make education more inclusive, enabling learners with special needs (e.g. students with learning disabilities) to benefit from more visual and interactive learning approaches tailored to their specific needs [7].

It should be noted that the impact of AR on learning is not universally positive. For example, studies have shown that the use of AR can sometimes result in cognitive overload for learners, due to the complexity of interactions and the need to juggle between virtual and real information [11]. Furthermore, in some situations, the integration of AR may not offer significant advantages over traditional pedagogical approaches, such as the use of conventional visual aids, particularly in terms of learning efficiency [7]. In addition, the literature points out that the design of AR learning environments does not always meet learners' specific expectations and needs, which can limit their satisfaction and engagement [10].

3.2. Education and Artificial Intelligence

Artificial intelligence (AI) refers to the ability of a computer system to simulate human cognitive functions such as learning, reasoning, decision-making and problem solving [11]. It relies on algorithms capable of processing large quantities of data, detecting patterns and generating solutions adapted to complex problems.

One of the most significant contributions of AI is the personalization of learning. By analyzing data from learners, such as their performance, strengths and weaknesses, interests and preferences, AI can tailor educational content and teaching methods to meet the specific needs of each individual. This ability to personalize enables learners to progress at their own pace, while benefiting from targeted and tailored support, making education more equitable and inclusive [12;13].

What's more, by combining AI and AR in learning environments, learners acquire essential skills for success in a complex, digital society [14].

3.3. Personalizing learning through AR and AI

In the educational context, the integration of emerging technologies such as artificial intelligence (AI) and augmented reality (AR) represents an innovative response to diversified learning needs. AI makes it possible to collect and analyze learner data to personalize educational content in real time, adjusting exercises and offering recommendations tailored to each learner [15]. At the same time, AR offers immersive environments that allow learners to interact with 3D simulations and objects, making learning more visual and experiential [10]. For example, in fields such as science, AR can offer visualizations of invisible or complex phenomena, facilitating learner understanding and engagement. The integration of AI and AR in education thus makes it possible to create learning experiences tailored to students'

individual styles, while increasing their motivation and understanding [1]. However, this personalization also raises challenges regarding data accessibility and confidentiality, which require thoughtful and ethical approaches to ensure equitable learning for all [16].

The design of educational devices based on AI and AR requires special attention to meet the varied expectations of users and guarantee their satisfaction. These innovations represent a major step forward towards more inclusive and adaptable education, but they require a rigorous methodological framework to assess their effectiveness and acceptability among different groups of learners.

4. Methodology

In order to carry out this research, we will adopt a multi-stage methodology, combining theoretical rigor with a practical approach.

The first stage will consist of an in-depth analysis of the existing literature on the use of augmented reality (AR) and artificial intelligence (AI) in education, which will enable us to lay the foundations for the theoretical framework of the study.

In a second phase, we will launch a series of preliminary experiments with groups of learners; the aim will be to gather detailed data on learners' learning styles, individual preferences and levels of engagement. To do this, several approaches will be explored to better understand how learners interact with immersive AR environments and AI-personalized content. Tests will include direct observation of learners' interactions with pedagogical scenarios designed specifically for different learner profiles.

In parallel, we will develop a pedagogical device integrating AR and AI, taking care to adopt an iterative approach. This involves designing the application, then progressively adapting it according to user feedback, to optimize its effectiveness and engagement. This process will enable the device to evolve continuously according to the needs expressed by learners and the results obtained.

Finally, through successive experiments, we will analyze the data collected (quantitative, qualitative, and interaction traces) to measure the real impact of AR and AI on learning. These assessments will serve as a basis for proposing practical recommendations on the integration of these technologies into learning environments.

The aim of this methodology is to ensure that the impact of pedagogical innovation is measurable and applicable in concrete terms, taking into account learners' feedback and needs at every stage of the process.

5. Expected results

- An in-depth understanding of the benefits and limitations of AI-AR integration in learning environments:

A key outcome of this research will be a detailed analysis of the benefits and challenges associated with the joint use of AI and AR in education. This study will aim to clarify the extent to which these technologies can meet the varied needs of learners, particularly in terms of personalization, engagement and accessibility. The aim will be to understand how AR, by offering immersive environments, and AI, by analyzing learners' behavioral data, can complement each other to enhance the educational experience. However, potential challenges linked to the integration of these technologies will also be explored, such as the cost of implementation, the availability of suitable educational resources and the resistance to change of certain educational stakeholders. Particular attention will be paid to the limits associated with excessive personalization of learning paths, which could, in some cases, make learners overly dependent on technological systems.

- A theoretical framework for designing customized educational systems:

This project will also develop a theoretical framework detailing the principles of learning personalization through AI and AR, specifically focused on individual learning styles. This theoretical framework will combine traditional pedagogical approaches with the possibilities offered by immersive technologies. It will include guidelines on how to structure educational content according to learner types and how AI can adjust learning paths in real time to maintain a balance between challenge and support. The theoretical framework will also help define criteria for evaluating the effectiveness of these systems, taking into account elements such as student engagement, autonomy, information retention and overall satisfaction.

- Practical recommendations for educational institutions and educational technology developers:

Based on the results obtained from the experiments and the analysis of the data collected, concrete recommendations will be formulated for educational institutions and educational technology developers. These recommendations will aim to provide guidelines on the integration of AI and AR into learning environments, in order to facilitate their adoption in schools. Among the expected recommendations will be suggestions on the design of flexible educational content adapted to different types of learners, advice on the ongoing assessment of student progress, and strategies for overcoming technical and organizational barriers to the implementation of these technologies. In addition, these recommendations will also be designed to help schools maximize the impact of these tools in terms of accessibility, inclusion and optimization of learning outcomes.

In summary, the expected results of this research will help to light the way for better integration of AI and AR into educational systems, while providing a solid foundation for the design of adaptive, interactive and accessible learning tools.

6. Conclusion

The integration of AR and AI in education, geared towards adapting to learning styles, represents a significant step forward in enabling the personalization of content and maximizing learner engagement through interactive and immersive experiences. This innovative approach responds to a growing diversity of learners while promoting inclusive and dynamic education. However, for widespread adoption, it is crucial to develop robust and accessible models.

Future work could investigate the impact of AI and AR on specific learning styles in terms of effectiveness and engagement. In addition, the development of theoretical models suitable for immersive environments and their validation in a variety of pedagogical contexts deserve particular attention. Research should also include standardized evaluation frameworks to measure the real impact of personalized learning. In addition, exploring the ethical and legal implications, as well as strategies for making these innovations accessible in low-resource environments, remains essential.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed

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