Augmented Reality in Higher Education: Interactions in LLM-Based Teaching and Learning

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Abstract. With the increasing demand for pedagogical innovation in the digital age, this study focuses on the integration of Augmented Reality (AR) and Large Scale Language Models (LLMs) to enhance the digital competencies of future teachers. Through a qualitative approach, a focus group of six simulated LLM participants was used to examine how this emerging technology can enhance teaching-learning procedures. The methodology included group interviews or focus groups, looking to capture the depth of the educational experience enriched by these tools. The results showed a noticeable increase in student motivation and engagement, evidencing an improvement in their digital and problem-solving skills. The use of AR, in combination with LLMs, eased more interactive and collaborative learning, allowing participants to understand complex concepts more effectively through enriched visual experiences. This finding underscores the importance of these technologies in creating dynamic and participatory learning environments. This study's recommendations emphasize the importance of incorporating advanced technological tools, anticipating the potential of LLMs and AR to prepare future educators in real-world contexts, and promising to transform 21st-century education. This approach not only enriches the digital competencies of future teachers but also opens pathways towards more active and participatory teaching methodologies, projecting a future where education fully benefits from technological innovation.

Keywords: Augmented Reality · Technology Integration · Curriculum Development

1 Introduction

The integration of emerging technologies in education, particularly Augmented Reality (AR), is vital to align pedagogical practices with Information and Communication Technology (ICT) capabilities, preparing students for a globalized world. AR enhances experiential learning and equips students with real-world challenges, as mentioned by [1–3]. The need for digital competencies in AR is highlighted by frameworks such as [4] and [5]. [6] stresses the importance of integrating old and recent technologies in evolving educational practices. AR, in particular, offers immersive learning experiences, improving

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students' understanding and retention of complex concepts through experiential learning. These needs are underscored by various initiatives in Spain. This emerging technology is chosen for its potential to revitalize teaching, allowing immersive and enriching interactions with educational content. According to [3], it helps discovery-based learning, enhances motivation through educational games, and fosters understanding and retention of complex concepts.

1.1 Justification

The research is justified by the need to align pedagogical practices with the capabilities of ICT, preparing students for a globalized world through AR. The significance of integrating this emerging technology lies in its potential to enhance experiential learning and equip students with skills to face real-world challenges [1–3]. This approach is underpinned by the digital competencies framework established by [4] and [5], emphasizing the necessity to develop digital competencies in AR to innovate and improve pedagogical processes.

The investigation adopts a practical approach to identify the digital competencies in AR required for future educators, aiming to promote educational innovation and the enhancement of pedagogical processes. This study explores how the acquisition of digital competencies in AR by undergraduate students facilitates problem-solving and the transfer of technological knowledge to new learning situations. This response to a call to action to foster innovation in education through the development and implementation of AR, highlighting its potential to revitalize teaching through immersive and enriching interactions with educational content [3].

Finally, the justification is based on evidence from recent studies that demonstrate significant benefits of AR in terms of student motivation and academic performance, as well as its ability to encourage active and collaborative learning methodologies [7, 8]. However, the existence of challenges and limitations for the effective implementation of AR in educational settings, such as the digital divide and a lack of resources in some institutions, is also recognized, requiring ongoing commitment to professional development and quality educational content creation [9, 10]. This research aims to contribute to the educational field by offering insights on how to overcome these barriers and maximize the educational benefits of AR.

1.2 Objectives and Research Questions

The research objective is: Assess the effectiveness of integrating Large Scale Language Models (LLMs) within AR environments to enhance the digital competencies and pedagogical approaches of trainee teachers, focusing on innovative teaching methods and improved learning experiences. The research questions are:

- How do AR-based pedagogical tools influence the pedagogical strategies adopted by educators in teacher education programs?
- What effects do AR-based educational interventions have on learning outcomes and levels of student engagement in teacher education programs?

2 Literature Review

Although Augmented Reality (AR) is a technology that conceptually dates back to the 1960s, its practical application in education began to flourish with the popularization of smartphones in 2007 [30]. Recent research highlights its usefulness for improving interactivity and engagement in the classroom, as well as for facilitating the understanding of complex concepts through interactive three-dimensional models [31].

On the other hand, Large Scale Language Models (LLM), such as GPT (Generative Pre-trained Transformer), are artificial intelligence systems designed to understand, generate, and translate text into human language with a high degree of sophistication [32].

LLMs have experienced an advance in their capability and accuracy thanks to innovations in deep learning and natural language processing. In addition, they are applied in diverse fields including, but not limited to, natural language processing, content creation, and even the creation of educational tools, showing their flexibility and broad utility in addressing complex language-based tasks [33]. In education, AR has seen significant growth, underscoring its impact on enhancing teaching and learning processes. Recent studies have shown that AR offers enriching educational experiences, promoting more interactive and engaging learning [11, 12]. These technologies not only allow for more attractive content visualization but also facilitate the understanding of complex concepts through interactive three-dimensional models [13, 14].

On the other hand, the integration of AR in education has revealed significant benefits in terms of student motivation and academic performance [7, 8]. Students not only show increased interest and enthusiasm toward educational content but also show improvements in information retention and comprehension. Additionally, AR fosters active and collaborative learning methodologies, resulting in a deeper and more meaningful educational experience [15].

However, the challenges and limitations of implementing AR in educational settings should not be ignored. One of the main obstacles is the digital divide and lack of resources in some institutions, which can limit access to these technologies [16, 17]. Moreover, the effectiveness of AR is contingent on the quality of educational content and teacher training in these new technologies, necessitating continuous investment in professional development and content creation [9, 10].

Despite these challenges, the future of AR in education appears promising, with considerable potential to transform how various subjects are taught and learned. Continuous innovation in AR technology and its increasing accessibility indicates that its integration into education will expand further, offering more immersive, personalized, and effective learning experiences [18, 19]. Therefore, educators and policymakers must recognize the value of AR and work towards overcoming existing barriers to its effective implementation.

3 Research Design

It is based on a participatory action research design since it aims to improve concrete practices, in this sense the integration of AR digital competencies. [20] mentions that the steps to follow for this method are:

– Identification of research opportunities
– Development of an action plan for the specific opportunity and/or situation identified.
– Implement the action plan and verify that it works.
– Reflect, analyze, interpret, and integrate the results and thus carry out a re-planning.

As a technique for this research design, the focus group with LLM is used, as it collects information on the (why, how, and what) regarding the richness of the individual and group experiences of the participants through a script of questions [21]. Thus, the focus group serves for diagnosis and later for reflection on implementation to gather opinions, perspectives, and improvements for future research. In this context, the qualitative design would be structured in interrelated phases to ensure continuous participation and feedback from participants. The following description is a detailed representation of how this process would be carried out (Table 1):

– Initial preparation and planning:

  - Identification of the educational community and key stakeholders.
  - Creation of an interdisciplinary research team including education and technology experts.
  - Clear definition of research objectives and questions in collaboration with stakeholders.

– Data collection:

  - Use of participant observation techniques to record interactions and learning dynamics.

– Data analysis:

  - Part of a deductive method, because the units or categories of analysis established by the research questions are already known.
  - Transcription and detailed analysis of group sessions and observation notes.
  - Comparison of results with existing literature to validate and contextualize findings.

– Evaluation and action:

  - Collaborative discussion to identify action strategies to address challenges and maximize identified benefits.
  - Ongoing iterations of the implementation and evaluation process based on participant feedback and research findings.

This approach is based on participatory action research and the use of focus groups that will provide an in-depth understanding of the perspectives of the learners involved, which in turn will enrich the curriculum design and implementation of AR in the educational environment. It will also foster a collaborative learning environment and a culture of feedback that promotes continuous improvement and innovation in education.

Table 1. Units of analysis.

Unit of Analysis	Qualitative Method: Focus Group
Impact of AR	– Discussion on how AR implementation has influenced learning and teaching – Exploration of perceived changes in interaction and engagement with learning material
AR Digital Competences	– Assessment of skills and knowledge acquired in AR – Discussion on the challenges and benefits of integrating AR into the educational process
Impact Assessment with AR	– Analysis of personal experiences using AR for assessments – Opinions on the effectiveness of AR as an assessment tool
Practical Applications with AR	– Account of specific cases where AR has been applied in teaching – Discussion on future possibilities and limits of AR in education

Note. The graph represents the units of analysis considered in the focus group

3.1 Focus Group: Data Collection Instrument

The focus of the study will be the use of simulated focus groups with LLMs it is proposed the inclusion of six simulated participants. These participants will represent the responses and experiences of university students in the context of AR. According to [22], focus groups allow for capturing subjective comments that can be evaluated to understand perceptions, emotions, attitudes, and motivations. This interactive and collaborative approach, also highlighted by [28], promotes the exchange of thoughts and opinions, which is crucial to understanding the attitudes and motivations behind participants' behavior. [29] highlight that focus groups generate creative solutions and ideas for implementation strategies. This simulation method using LLM will enable a deeper and more diverse understanding of students' digital competencies in AR, thus contributing to the creation of more effective interventions in the educational context.

For the inclusion of a simulated focus group using LLMs with six participants, the following adaptations to the research instrument by [22] will be considered:

– Planning the Use of the Simulated Focus Group: Determine how participant interactions and responses will be simulated using LLM.
– Select appropriate qualitative data analysis software (NVivo).
– Develop Data Collection Instrument: Create a protocol to simulate the focus group discussion, including generating realistic responses and dialogues.
– Define key questions and themes that will guide the simulation.
– Selection of Simulated Participants: Generate profiles of simulated participants (students) that reflect diversity in experience and background.
– Implementation and Analysis of the Simulated Focus Group: Conduct the simulation of the focus group discussion, ensuring equal participation of the six simulated participants.
– Analyze the simulated conversations to identify patterns, trends, and perspectives.

This approach will allow assessing perceptions and experiences related to AR in education in a controlled and detailed manner while maintaining the academic rigor of the study. The implementation of LLM in simulated focus groups represents a significant advance in educational research, offering new perspectives and understandings about the use of emerging technologies in teacher education.

4 Results

The analysis of the focus group data simulated with LLMs generated relevant themes that focus on the application of AR in education. With 63 mentions, "Practical Applications_RA" is seen as the backbone for the advancement of interactive learning. On the contrary, "Digital Competencies_RA", with 37 mentions, reflects the need to train educators in skills relevant to the digital age [23].

In addition, "AR_Impact_Evaluation" and "AR_Impact_Learning_Impact", with 32 and 41 simultaneous mentions, suggest a reflection on how to quantify the effect of AR on educational learning achievements. The reduction in the frequency of references to the "ICT" code is interpreted as an already assimilated integration of the technology, in which AR stands out in terms of transformation. The representation of gender symmetry is, on the other hand, an attempt to balance perspectives in research, in line with current trends in inclusion and diversity.

However, the word cloud captures key concepts that emerged from the focus group. Words such as "experiences", "learning" and "content" demonstrate a focus on creating immersive educational material, supporting [24] claim about the importance of meaningful experiences in digital learning. In addition, the prominence of terms such as "skills", "resources" and "training" reflects the need to develop digital competencies to maximize the use of technology in education, as emphasized in the research [25] (Fig. 1).

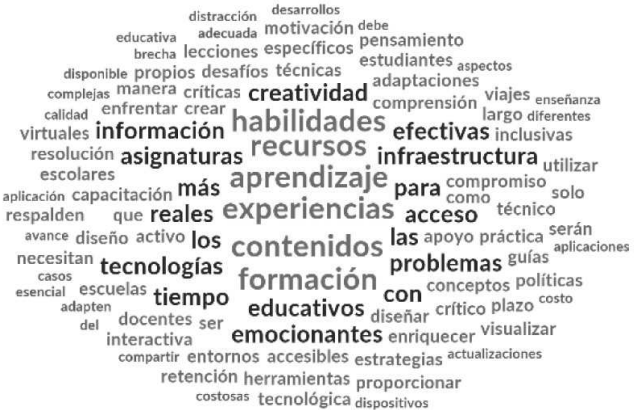

Fig. 1. Word cloud derived from a qualitative focus group analysis.

The recurrence of words such as "exciting" and "creativity" in the word cloud indicates a highly positive assessment of AR as a student engagement technology, which is consistent with the literature that identifies AR as a means of stimulating active thinking in educational processes [15]. This emphasis on emotive and creative content reinforces

the importance of innovative pedagogical strategies that include emerging technologies to enrich the learning experience [26].

The presence of terms such as "technologies", "infrastructure" and "access" reflects structural challenges and requirements, emphasizing the importance of adequate infrastructure for innovative educational technologies [23]. This terminology describes the need for robust educational resources that are essential for the long-term adoption of AR in pedagogical settings [27].

As for the relationship diagram of the focus groups, it illustrates the multifaceted connections between participants and key concepts in the context of AR in education. The lines represent the frequency and intensity of discussions on specific topics, with "Practical_AR_Applications" leading the way in mentions, reflecting their central importance in interactive learning and pedagogy today [26]. On the other hand, "Digital_RA_Skills" and "Assessment_Impact_RA" show strong relationships, highlighting the growing need for effective digital skills and assessments within educational settings using AR [25] (Fig. 2).

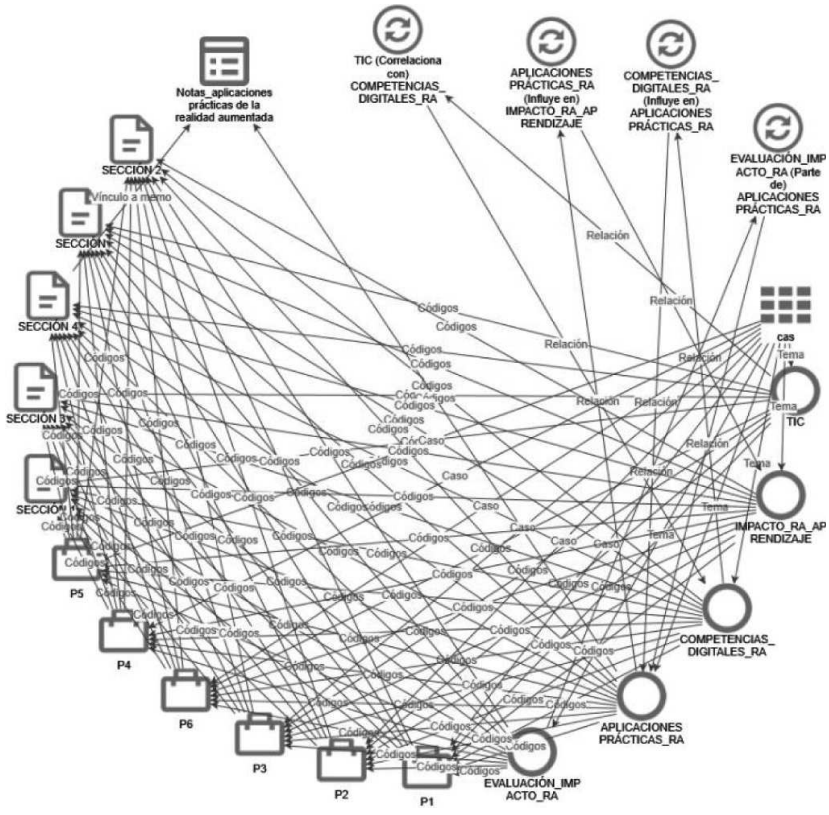

Fig. 2. Focus group relationship map using LLMs to analyze AR in higher education.

The interactions between the codes and the participants show that the AR learning experience depends not only on ICT but also on the development of digital competencies and the evaluation of pedagogical impact. This focus on "Impact_RA_Learning" is in line with the theory that recognizes AR as a catalyst for knowledge retention [23]. Lines between genders and codes indicate differences in interaction with AR, supporting the need for inclusive approaches in technology education [24].

To interpret the graph below, based on Pearson's correlation coefficient, the relationship between the mentions of the codes in the focus group sessions is considered. The lines connecting the codes suggest that "hands-on Applications_RA" has a significant correlation with "digital Competencies_RA", meaning that there is a direct relationship between the practical application of AR and the development of digital competencies, as noted by [15] (Fig. 3).

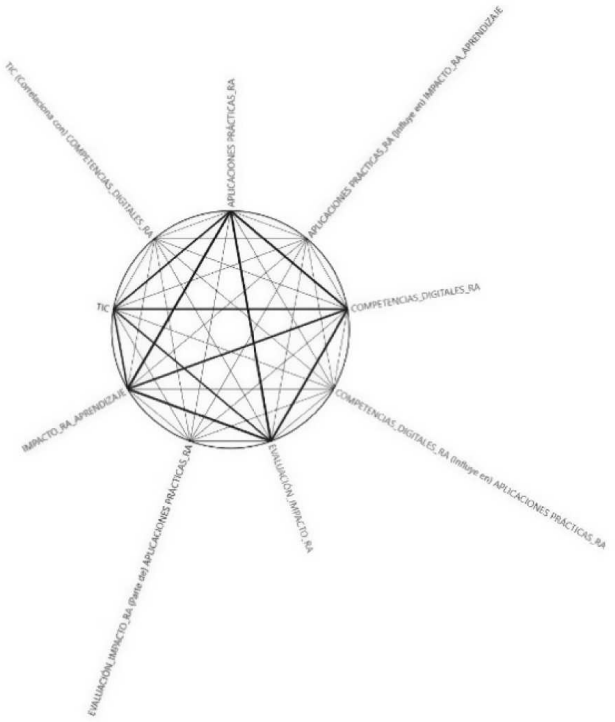

Fig. 3. Pearson's correlation radar for topic analysis in the focus group on AR.

The discussion on "AR_Impact_Evaluation" and "AR_Impact_Learning_Impact" highlights the importance of assessments in understanding the value of AR in education, in line with [24]. In conclusion, the results underscore the need for AR teacher training that combines technical and reflective skills to prepare students for the digital age, as suggested by [26].

5 Conclusions

This study's conclusion about the application of AR in education, using focus groups simulated with LLMs, reveals several key insights. First, AR is identified as a crucial potential catalyst for interactive learning, emphasizing the need to train teachers in digital competencies relevant to the digital era. The simulated group discussion highlights the significance of creating immersive and meaningful educational materials, underscoring the need to focus on developing skills and resources to maximize the use of technology in education.

Secondly, the results reflect a positive assessment of AR as a technology to stimulate student engagement, consistent with the literature that identifies AR as a means to

promote active thinking in educational processes. The emphasis on emotional and creative content supports the importance of innovative pedagogical strategies that include emerging technologies to provide an enriched learning experience.

Finally, the presence of terms such as "technologies", "infrastructure" and "access" in the focus group analysis reflects structural challenges and requirements for the effective implementation of AR in educational settings. This describes the need for substantial educational resources for the long-term adoption of AR in pedagogical settings, suggesting that teacher training in AR should combine technical and reflective skills to prepare students for the digital age.

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