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Immersive technologies for engineering teaching: an approach applied to higher education

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Abstract: The evolution of the educational environment requires constant adaptation to emerging technological trends. Within this transformation, conventional teaching tools, such as traditional whiteboards, are gradually being replaced by digital resources like projectors and interactive whiteboards, which enhance student engagement and interaction with learning materials. This paper explores the integration of Augmented Reality (AR) as an instructional resource in the context of Mechanical Engineering education. The study addresses a common challenge faced by students: the difficulty in comprehending three-dimensional structures when presented in two-dimensional formats. To investigate this, a bibliographic review of academic literature was conducted to map current findings and approaches in this field. The review highlights that incorporating AR into the classroom is feasible and beneficial, provided that educators receive adequate training to effectively facilitate its use. The findings suggest that AR can enrich the learning experience in Mechanical Engineering by fostering deeper conceptual understanding and offering a practical, applicable solution for enhancing education through immersive technology. Palavras-chave: Mechanical Engineering; Teaching-learning; Augmented reality; Technology.

Keywords: *Technology-enhanced learning*

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I.INTRODUCTION:

Augmented Reality (AR) is a technological tool that enhances interactivity with projected elements. Through internet-connected mobile devices, both educators and students can access AR features, which contributes to better comprehension of the content addressed in class. As noted by Mekni and Lemieux (2014), the widespread accessibility of smartphones, particularly after 2010, enabled the expansion of interactive AR tools within academic settings. In this context, Moran (2004) highlights that one of the most common complaints from university students concerns the traditional manner in which subjects are taught, pointing to the need for pedagogical innovations that incorporate technology into the teaching-learning process. Although AR is not a new technology—with its development dating back to the 1960s—its use in educational environments remains limited. A key barrier to its adoption is the lack of adequate teacher training. Various studies explore the benefits of AR in project-based education, such as the research by Fernández, Raposo, and Costa (2007), which analyzes the reduction of construction errors in architectural planning using AR tools. Furthermore, Lopes, Vidotto, Pozzebon, and Ferenhof (2019) mention its application in interior design and building restoration processes. The advancement of this technology has stimulated discussions about its integration into educational practices. Mechanical engineering programs aim to train professionals who are capable of addressing the challenges of the labor market. In this context, computational modeling emerges as a valuable strategy, enhancing the assimilation of key concepts and the development of new knowledge.

II.MATERIALS AND METHODS

- This research organizes its materials and methods based on the following thematic axes: 2.1: Augmented Reality (AR); 2.2: Teaching of Mechanical Engineering; 2.3: Applications of AR in the instruction of Mechanical Engineering-related subjects. Following the literature review on the aforementioned topics, a spreadsheet was created to compile the data from the selected publications, allowing for the identification of common points and patterns among the studies.Augmented reality (AR)
- Augmented Reality plays a key role in enhancing learning across various disciplines. It offers educators a user-friendly and accessible technology that enables content exploration through active learning methodologies, in which students are positioned as the primary agents in constructing their own knowledge, supported by the teacher. As defined by Azuma (1997), AR is a system that overlays virtual elements onto the physical world, enabling real-time interaction between virtual and real components, with emphasis on tangible objects. Thornton, Ernst, and Clark (2012) support this definition, emphasizing AR's potential as a powerful tool in technology-based educational curricula. Unlike Virtual Reality (VR), which immerses users entirely in a simulated environment, AR builds upon the real world by integrating complementary digital elements, as noted by Romero and Hounsell (2018). According to Azuma (1997), the development of AR began in the 1960s. In addition to improving educational practices, it is applied in fields such as equipment assembly and maintenance, as discussed by Justimiano, Gomes, Motta, and Sementille (2021). Other applications include aviation training (Figure 1), visualization of hydrosanitary systems (Figure 2), and understanding architectural and engineering components (Figure 3), among others. Beyond its various implementations, Augmented Reality (AR) contributes significantly to the instructional process within the Topography subject area, as noted by Moreira and Ruschel (2015). This methodology incorporates a sandbox system integrated with motion detection sensors, a digital projector, and dedicated software. In the context of geography education, numerous investigations have examined the utility of AR technologies. Herpich et al. (2015), for example, highlighted how AR can support the development of case-based activities and problem-solving exercises with students.

- Teaching in the field of mechanical engineering Educating future Mechanical Engineers is an inherently intricate process. The curriculum spans a broad spectrum of scientific and technological domains, shaping the professional competencies required throughout the course. Over time, instructional practices have evolved, influenced by the cultural and technological transformations occurring in society. Such changes have been essential, as the mechanical engineering profession demands a comprehensive foundation across multiple disciplines to perform effectively. As Correa and Bazzo (2017) explain, teaching—as a professional activity—has been confronted with numerous challenges, largely stemming from ongoing changes within the professional and societal landscape. In the classroom, for instance, topics such as gear design necessitate foundational knowledge in subjects like Solid Mechanics, alongside a prior understanding of Machine Elements. The learning process is structured into multiple stages and requires handling complex mathematical formulations, performing unit conversions, and considering various factors that influence outcomes. Due to this complexity, solving even a single case can require significant time and cognitive effort from the student, both inside and outside the classroom. According to Rocha (2019), greater emphasis should be placed on the teaching of machining within Mechanical Engineering programs, particularly through the sustainable creation of instructional tools. By replacing conventional cutting tools with alternatives made from miriti (a type of palm), instructors can promote cost-reduction strategies while maintaining tool functionality, thus enhancing educational accessibility.
- Utilization of ar in mechanical engineering education Due to its versatility and wide-ranging applicability across numerous academic disciplines, Augmented Reality (AR) is particularly well-suited for integration into subjects aligned with Mechanical Engineering. Its capacity for fostering interactivity and enabling spatial, three-dimensional visualization equips students with a deeper understanding of mechanical components and how these systems function in unison. This section aims to highlight key instances of AR application within the domain, underscoring its potential to enhance student learning experiences. As noted by Araújo and Schorn (2017), educational discourse increasingly includes topics such as public policy, curricular development, and the integration of digital technologies—emphasizing their relevance in modern academic environments.

III.RESULTS AND DISCUSSIONS

The literature review reveals significant opportunities for implementing AR in the instruction of Mechanical Engineering-related disciplines. As part of the broader metaverse framework—which bridges physical and digital realities—AR provides partial immersion, enabling dynamic interaction between virtual elements and the real world. Based on the studies analyzed in the previous section, AR emerges as a practical alternative to traditional lab infrastructure, offering cost-effective solutions for educational institutions. Mechanical Engineering educators can leverage AR to explore the structure and functionality of machinery components in a three-dimensional format alongside their students. As noted in the reviewed sources, a simple internet-connected smartphone is sufficient to access AR content, transforming the device from a classroom distraction into a valuable learning companion. The growing discourse around mobile phone use in education underscores the potential of AR as a powerful instructional tool capable of improving the delivery of technical content. Given the complex nature of Mechanical Engineering education, it becomes evident—from the literature reviewed—that student development must go beyond technical training. It should also include cultural awareness and environmental responsibility.

IV.CONCLUSIONS

The systematic review of publications concerning AR, its role in Mechanical Engineering education, and its specific applications in course-related subjects confirms the value and usability of this technology in academic contexts. AR offers various practical uses that support student-centered knowledge construction, positioning the educator as a facilitator who bridges the gap between theoretical content and practical understanding. Considering the broad range of subjects included in Mechanical Engineering programs, students often face challenges due to reliance on conventional teaching approaches, which typically involve chalkboard lectures and textbook-based instruction. This traditional framework tends to limit students to passive roles, reducing opportunities for critical engagement and hindering both academic and professional development. In response to these challenges, this study aimed to highlight the diversity of content in Mechanical Engineering programs and proposed AR as a strategic alternative to address learning difficulties in core subjects. Furthermore, it advocated for the educational use of mobile devices in the classroom, allowing students to interact with complex content in three dimensions and in real time. This interactive learning process not only reinforces conceptual understanding but also simulates professional scenarios encountered in real-world engineering practice.

V.REFERENCES

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