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RESEARCH PAPER

A Review of AR/VR Technologies in Simulation-Based Learning: Current Trends and Future Directions

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***Abstract*—The Innovations in cutting-edge technology, such as VR and AR, are changing the face of education. This study delves at the potential integration of VR and AR technology with simulation-based learning (SBL), with a focus on current advancements and possible future directions. As cutting-edge teaching technologies, AR and VR enhance immersive learning environments and offer fresh strategies for student involvement. The review begins by examining the evolution of VR technology, highlighting its applications in education, from early flight simulators to contemporary immersive educational tools that enhance student motivation and learning outcomes. AR, on the other hand, offers context-rich visualizations that foster interactivity, especially in disciplines such as language education. The benefits of AR, such as enhanced student performance and teamwork, are covered in the study. Furthermore, it emphasizes the growing use of simulation-based learning in healthcare education, where VR and AR are used to enhance clinical skills, communication, and critical thinking. There are still issues with resources, accessibility, and integration, even though AR and VR have great potential in education. In order to overcome these obstacles and advance research to provide more efficient, scalable, and accessible educational experiences across disciplines, the paper ends by outlining possible future possibilities for AR/VR technology in SBL.**

Keywords—Augmented Reality (AR), Virtual Reality (VR), Simulation-Based Learning (SBL), Learning Engagement, Simulation Education.

I. INTRODUCTION

Virtual reality (VR) technology produces an interactive virtual environment in three dimensions that may be explored with the use of specialized electronic gear, like a helmet or gloves, in a manner that mimics the user's natural sense of touch[1]. VR as an idea is not novel.; in fact, the US Air Force employed a digital VR system as a training flight simulator in 1966, which was the first recorded usage of the technology [2]. There are now two varieties of VR: immersive VR, which makes the user feel as though they are physically there in a virtual environment, and non-immersive VR, which can mimic either actual or made-up locations[3]. VR technology is growing in popularity across a range of businesses globally [4], includes education, as it advances and is more reasonably priced [5]. The usage of head-mounted displays is now required for immersive virtual reality versions of educational resources that were originally developed for mobile or PC platforms [6]. The underlying presumption is that more immersion will improve learning and increase student motivation.

The state-of-the-art technologies of augmented reality and virtual reality have found several uses in various industries[7]. A kind of 3D technology known as (AR) superimposes digital data onto the physical environment[8]. Through the use of object identification and graphic computing technology, it might improve users' perception of the actual environment by adding virtual things [9]. Improved performance, more motivation and engagement, and encouraged student participation are some of the benefits of (AR) for education [10]. The language training area stands to benefit greatly from augmented reality's contextual visualization and learning interactivity characteristics, which allow users to engage with virtual material and show virtual information in rich contexts.

Simulation-based learning (SBL) has been used to assist students and professionals develop a variety of skills in healthcare education. It is recognized as a safe, real-world, experiential learning environment [11]. Along with methods and skills unique to a certain speciality, skill development include broad competencies including communication, clinical reasoning, and critical thinking [12]. The chance it presents to bridge the gap between classroom learning and real-world application, preparing students for their future employment or assignments [13]. SBL forms are essential to medical and nursing schools because of the type of skill development that is needed. SBL has historically not been incorporated into all dietetic programs because of a lack of funding for creating realistic, high-quality simulation situations, access to simulation labs, and qualified personnel to carry out SBL.

A. *Organization of the Study*

This paper has the following structure: An introduction to VR and AR technologies, with details on their characteristics and evolution, is given in Section II; Section III discusses simulation-based learning in education, emphasizing how AR/VR enhances training through immersive and interactive environments; Section IV explores current trends in AR/VR applications across healthcare, engineering, and corporate training, highlighting advancements in surgical simulations, technical training, and soft skill development; Section V presents relevant literature and case studies to evaluate AR/VR's role in education; and Section VI offers conclusions and recommendations for future research directions, focusing on emerging user interfaces, evolving pedagogies, and research gaps in digital learning.

II. Fundamentals Of Ar/Vr Technologies

One of the innovative technologies is VAR [14], is taking front stage in their lives. The general consensus is that VR is a technology that creates an artificial environment where users may move about and interact with objects. The converse is true with AR, which is typically described as a technology that lets users engage with digital items while physically present in the real world[15]. A growing number of businesses have attempted to enter the digital realm in recent years, with Meta and NVIDIA leading the global shift to a VAR future [16]. VR has come a long way and is already finding applications in several fields, such as simulation and entertainment. The entertainment business is witnessing a meteoric rise in the popularity of head-mounted VR headsets, such as Oculus Quest 2 and Sony's PlayStation VR. A lot of people call these headsets the "next generation" of gaming since they put players in an entirely artificial environment made for the game [17].

A. Augmented Reality (AR)

Boeing researcher Thomas Preston Caudell developed the concept of utilizing augmented reality (AR) to study assembly diagrams as a tool for industry in 1992 [18]. Several definitions of AR have been proposed in recent years, with the most popular one coming from Paul Milgram's work in the field of industrial engineering[19], Professor Fumio Kishino of the Electrical, Computer, and Energy Engineering Department at the University of Toronto, together with [20], Osaka Univ. A number of realities, according to their idea, merge to form a continuum that links the physical and digital realms[21]. The main function of augmented reality (AR) is to create links, either directly or by user involvement, connecting device or information-generated data with the actual world. The user can access an interface for a physically enhanced environment that is enhanced by technology in this scenario. The goal of augmented reality technology is to augment the user's view of their physical or virtual world by superimposing digital data on top of the user's existing view in real time. Integrating data (numbers, characters, symbols, music, video, and pictures) with the user's perception of the physical environment is a common practice in many display systems.

B. Virtual Reality (VR)

In digitally linked world, VR and AR are becoming more and more popular because of their enormous strategic possibilities [22]. With significant ramifications for several research and projects, VR and AR are already establishing trends in education and creativity [23]. Virtual reality is defined and enhanced by the terms "information," "innovation," "creativity," "immersion," "fascination," and "technology" all used together." The quantity of scientific papers has significantly grown[24], illustrating how the global academic environment has an influence [25]. The most advanced form of HCI is virtual reality, which enables the user to engage with an augmented reality setting in real time. Through the use of visuals to create sensations and the ability to directly intervene inside the virtual world, this setting aims to excite some or all of the human senses. The user is completely unaware of his physical location since he is so immersed in a computer-generated, simulated, three-dimensional (3D) scene[26].

C. Mixed Reality (MR)

(DR), (VR) and (AR) are combined in mixed reality (MR) technology [27] for the simple reason that they have the potential to usher in novel graphical environments where the real and virtual coexist, enabling the simultaneous existence and interaction of digital and physical items. The fast advancement of hardware, particularly the debut of the Microsoft HoloLens head-mounted display, has opened up the usage of MR to some professional fields (Microsoft, Redmond, WA). Up till now, 3D visualization in operation planning has been accomplished in the medical industry via MR [28], the tourist industry for interactive visual and audio navigation, the aerospace industry for simulating space exploration settings [29], the engineering profession to encourage safety and communication throughout building sites and in other domains.

III. Simulation-Based Learning In Education

The limitations of real-world learning are removed by simulation-based learning, which offers practice-like learning and can be a helpful tactic for learning complex skills [30]. A simulation is a technology that mimics the features of an event or circumstance in real life[31][32]. They term it a "educational tool or device with which the learner physically interacts to mimic real life" and say it stresses "the necessity of inter-acting with authentic objects." For example, simulations can manage fewer frequent occurrences, make reaction times shorter, offer learners with fast feedback, etc., which allows them to practise and learn more effectively than in the actual world. This is what sets simulations apart as educational tools[33]. There are many more possibilities for instructional assistance, even though feedback is essential in simulation design since it tells users about the differences between the desired goal state and the current state (or behavior). The purpose of this research is to look at ways to give students better information and scaffolding. The use of simulation in medical education has several educational advantages, such as the ones listed below[34]:

- Deliberate practice with feedback
- Exposure to uncommon events
- Reproducibility
- Opportunity for assessment of learners
- The absence of risks to patients

IV. Current Trends In Ar/Vr In Simulation-Based Learning

The application of augmented and virtual reality technologies has greatly enhanced simulation-based learning across several domains [35]. Here's a summary of the latest trends in AR/VR uses across various fields, backed by recent studies.

A. Healthcare Education:

- **Virtual Simulations for Medical Training:** Simulation of surgical procedures, stroke and rehabilitation therapy, and training and medical education are some of the real-world medical applications of virtual reality (VR). To enhance surgical oncology capability and competency, Parham et al. (2019) created a low-cost virtual reality surgical simulator. Through the use of an Oculus Rift headset and a touch-hand controller, the surgical oncology simulation is executed in a virtual operating room that mimics the actual hospital setting[36].
- **AR/VR in Surgical Training and Practice:** The creation of a virtual environment for assessing various body parts for the purposes of diagnosis, planning, and

surgical training is the science underlying virtual reality. Using semi-transparent glasses, augmented reality overlays a 3D real environment customized for each patient onto the surgical field to improve the virtual image [37].

B. *Engineering and Technical Training*

- **Simulated Environments for Engineering Education:** Virtual and augmented reality's potential as a tool to assist in the instruction of "soft skills" is relatively new[38]. To the best of their knowledge, current VR and AR research initiatives are not utilized in educational contexts. However, the ability of VR and AR to place students in authentic scenarios makes them appealing for research into novel ideas [39].
- **VR in Design, Construction, and Manufacturing:** In Virtual design and construction helps businesses set clear goals. It involves using detailed models that show how design and construction projects will work. This includes the buildings themselves, how the design and construction teams are organized, and how the work is done." Many digital design tools and technologies[40] BIM, AR, GIS, the GPS, Some IT-based technologies, such as drone technology, 3D visualizations, "serious games," and cloud computing, have attracted interest as possible ways to enhance health and safety (H&S) procedures. On top of that, these technologies are being used more and more to make workplaces safer [41].

C. *Corporate and Business Training*

- **Virtual Reality for Soft Skill Development:** A continuous learning experience that is more realistic to the situation in which the abilities will be applied in the workplace may be obtained by practicing soft skills in virtual reality. VR is unique in that it allows for on-demand practice in realistic, multisensory, and engaging situations that are not possible with conventional teaching approaches. Strong feelings of presence and immersion are produced by VR, allowing for experiential learning in a secure virtual environment [42], where errors committed have no real-world repercussions.

V. Future Directions Of Ar/Vr In Simulation-Based Learning

Given that Figure 1's visual representation is obviously missing "High" level interaction and "Agency," this section will focus on describing potential future approaches by way of creating prototype case study applications that may show where the research is lacking and needs to be filled[43][44].

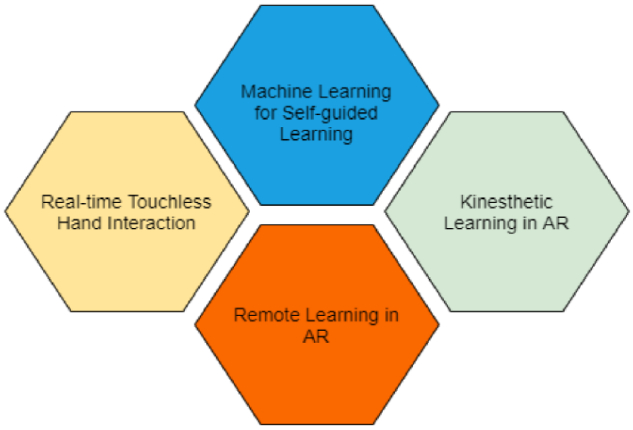

Fig. 1. Four core components of a future research approach in this area

The Innovations in instructional technology have been spurred by the "Suspending Classroom without Suspending Learning" approach, which has gained immense traction. This approach places primary focus on learning within the context of the person. Additionally, the virus's touch-based transmission increased demand for contactless or touchless technologies, that are essential for the digital revolution, particularly for educational uses of augmented reality (AR). Building more effective learning environments through the integration of agents, creating new kinds of learning pedagogy, and creating new sorts of user interfaces will, therefore, likely constitute the future of this topic [45][46].

VI. Literature Review

This study uses AR/VR technologies to emphasize earlier research in order to evaluate the various studies and offer a succinct overview, which is shown in Table I:

This research, Nur Fitria (2023) delves at the potential of augmented and virtual reality (AR/VR) for use in the classroom. A library served as the site of this investigation. According to the findings, augmented and virtual reality might be a powerful tool for both educators and pupils. With augmented reality, you may augment your real-world surroundings with text, audio, and visuals. Conversely, VR generates a whole new simulation setting that teaches a particular subject in a way that is interesting, dynamic, and experiential for students. Many topics make use of augmented reality (AR) technology in the classroom: 1) biology (the study of living things), 2) chemistry (atoms), 3) geography (the earth and space), 4) television and cinema (the showing of films), 5) informatics (the topology of computer networks), 6) mathematics (geometry), and 7) history (three-dimensional narratives). Several subjects incorporate virtual reality into their lessons, including the human digestive system, geometry, the earth's surface, history (including artefacts and temples), astronomy (including space), medicine (including surgical operation practicum), and aviation (including pilot training). But there are advantages and disadvantages to AR and VR[47].

The purpose of this study, Al-Ansi et al. (2023) is to contextualize how AR and VR have evolved in education over the past 12 years. Using subject analysis and text mining techniques, 1536 articles were chosen for additional examination. These papers were chosen from the Scopus database according to predetermined criteria, and WordStat was used to extract their titles, keywords, and abstracts. In order to identify the present state of the art in AR and VR literature production, applications, benefits, and future directions, hypotheses were developed and assessed based on prior research on AR and VR in education. The results show that the recent exponential development in the use of AR and VR in education may be attributed in large part to wearable technologies. The results, which are derived from secondary data, also emphasize how urgently educational institutions must embrace and modify new technology. The quick growth and maturation of AR and VR technology are leading to the emergence of new educational applications in the learning process. It is advised that researchers continue to explore potential applications of AR and VR in the classroom and develop flexible strategies to fully capitalize on these technologies' advancements[48].

This article, Garzón (2021) provides an overview of the development and current state of augmented reality technology in education. Accordingly, the study separates AR in education into three generations by analyzing its evolution. Additionally, the study highlights several significant issues with earlier AR implementations and, in order to maximize the advantages of AR for education, offers some solutions. AR is a technology that creates a more realistic and captivating experience by fusing computer-generated sensory data with real-world aspects. The first augmented reality application created specifically for use in educational settings was released twenty-five years ago[49].

In this study, Ghobadi et al. (2023) help advance their knowledge of how AR is embraced in challenging educational settings. By investigating how AR technology may be used in university instruction and delving into the ways that gender affects learning through AR application, the study enables us to expand the TAM. Augmented reality's (AR) popularity in the classroom is on the rise. Through the use of augmented reality technology, users may practice and learn in a virtual setting that permits risk-free failure, repetition, and correction. The current study assessed users' perceptions of utilizing augmented reality to learn challenging tasks. An augmented reality piling app that displays different phases of the building process must be used by users [50].

The study, Zhang and Wang (2021) of a meta-analysis of 61 research studies that looked at the efficacy of augmented and virtual reality in K–12 science classrooms are summarized in this report. The study's key findings were that although more research has been done on the application of augmented and virtual reality in K–12 scientific teaching, most of these studies have concentrated on the technology's technical benefits rather than its potential for enhancing students' understanding of scientific concepts. Additionally, In these research, the most commonly used approach was inquiry-based learning, the emphasis was on students gaining scientific knowledge rather than developing skills like critical thinking[51].

This study, Verner et al. (2022) assessed this method and looked at how these online interactions helped 99 first-year industrial engineering students learn about robot systems at home. Examining learning in the AR/VR environment and assessing how effectively it fosters integrative thinking and facilitates comprehension of robot systems were the goals. The students studied the TurtleBot2 and RACECAR MN robots in the augmented reality experiences they created with Vuforia Studio by deconstructing and altering their models and learning about their constituent parts. In the virtual reality experience, the students explored sensor-based robot navigation using the Racecar Sim simulator[52].

TABLE I. SUMMARIZES KEY STUDIES ON AR/VR IN EDUCATION, HIGHLIGHTING THEIR FOCUS AREAS, FINDINGS, CHALLENGES, AND CONTRIBUTIONS.

References	Focus Area	Key Findings	Challenges	Key Contribution
[47]	Using AR and VR in teaching	Both AR and VR are useful teaching and learning tools; AR adds digital components to reality, while VR produces immersive settings for courses like history, biology, and maths.	Implementation and customization barriers in educational institutions.	Demonstrates the AR and VR may be used effectively in a variety of areas and how they can have an impact on education.
[48]	Education's use of AR and VR during the past 12 years	Adoption of AR and VR in school is growing exponentially; wearable technology is driving development; implementation difficulties exist.	Difficulty in quick adoption and customization in institutions.	Identifies AR/VR adoption trends, challenges, and future research directions.
[49]	Evolution of AR in education	outlines the three generations of augmented reality in education and highlights obstacles and ideas to improve its advantages.	Challenges in prior AR applications in education.	Provides a historical perspective and categorization of AR evolution in education.
[50]	AR acceptance in complex learning environments	Examines AR's role in university teaching; gender influences learning outcomes; AR fosters safe, interactive learning.	Understanding gender-based differences in AR-based learning.	Extends the TAM model for AR in university education.
[51]	A thorough analysis of VR and AR in scientific teaching for grades K–12	Growing research interest in AR/VR for K-12 science; focus on technical aspects rather than deep subject integration.	Lack of emphasis on cultivating advanced cognitive skills like critical thinking.	Highlights the need for deeper AR/VR integration with science content.
[52]	AR/VR for learning industrial engineering robot systems	AR/VR enhances understanding of robot systems; students engaged with TurtleBot2 and RACECAR MN robots.	Assessing AR/VR's efficacy in hands-on engineering education.	Demonstrates AR/VR's potential in fostering integrative thinking in engineering students.

VII. Conclusion And Future Work

In many different fields, simulation-based learning has been significantly enhanced by the dynamic, captivating and immersive experiences that VR and AR provide. These tools enhance hands-on teaching, real-time feedback, and visualization, which helps people grasp difficult ideas. However, challenges such as high costs, hardware limitations, and accessibility issues still hinder widespread adoption. Despite these obstacles, advancements in AI, cloud computing, and cost-effective solutions continue to drive innovation, paving the way for broader implementation in education and professional training.

Future research should focus on reducing hardware costs, improving AR/VR accessibility, and enhancing user experience through better resolution, lower latency, and refined haptic feedback. Integrating AI-driven adaptive learning systems will personalize training and improve skill retention. Expanding AR/VR applications to soft skills training, remote education, and corporate learning will further strengthen their impact. Additionally, long-term studies on knowledge retention and cognitive effects will provide insights into optimizing these technologies for effective learning. Collaborative efforts between academia and industry will be essential for refining AR/VR solutions and making them more accessible for diverse educational needs.

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