

Education with Immersive Learning: A Study on Augmented Reality in STEM Education

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Abstract—Augmented Reality (AR) is a rapidly growing technology with many applications across various industries including Education. In this literature review, we focus on the current trends and applications of Augmented Reality in the field of education, particularly in understanding Physics, Mathematics, and Computer Science. With AR Technology students can understand various concepts easily and helps them visualize things. Marker-based AR can trigger the Digital content with interactive animations. Learning with the help of Visualization increases the creativity of students and enable them to improve their knowledge. The 3D visualization of AR creates interest in students as it can entertain them while learning. With the Integration of AR in Education, the gap between Education and Technology can be reduced

Index Terms— Augmented Reality, AR-based Visualization, Educational Technology, STEM Education, Digital learning.

I. INTRODUCTION

In Education, the demand for effective approaches to teaching Science, Technology, Engineering and Mathematics (STEM) subjects has never been more pressing. The traditional methods of delivering physics, mathematics, and computer science education often face challenges in captivating students' attention, particularly when surrounded by technologies [19]. Integrating Augmented Reality in Teaching is a prominent solution that not only addresses these challenges but also acts as a bridge between education and technology[10]. STEM Education acts as the core foundation for developing problem-solving skills, critical thinking and logical reasoning which is essential for the workforce in the future. However, the traditional teaching methods often struggle to meet the expectations of development of these skills in students who are accustomed to interactive and digital environments. Augmented Reality, with its ability to seamlessly blend both the virtual and physical worlds, it also has the potential to transform the learning experience by providing immersive and interactive content [5].

Some of the benefits of Augmented reality in STEM Education are :

- **Enhanced Visualization:** AR brings digital data to life, and offers an interactive explanation of complex theories in physics, mathematics, and computer science.
 - **Interactive Learning:** Students can interact with virtual objects and perform experiments in real-time, this improves hands-on learning experiences.
 - **Real-World Applications:** AR allows the integration of real-world applications, it demonstrates how mathematical and physical concepts are applied in real world situations with the help of virtual information.
- This literature review focuses on the current state of education and the application of augmented reality (AR) in

physics, mathematics, and computer science education. Through a comprehensive synthesis of existing research, our goal is to identify the emerging trends and challenges of AR in education, and explore the pedagogical implications for incorporation of AR technologies. This review not only provides the advantages of AR-enhanced learning experiences but also addresses that educators should navigate the effective integration of these technologies in the classroom.

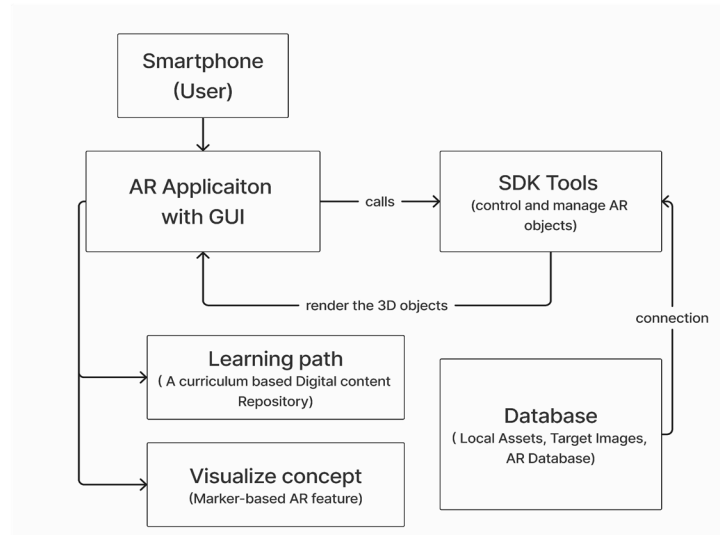


Fig. Architecture Diagram

II. ADVANTAGES OF AUGMENTED REALITY IN STEM

A. AR improves educational results

According to our research, AR increases student motivation, engagement, retention, and understanding of difficult ideas [1]. This directly contributes to student development and their performance, AR can also offer feedback, direction, and scaffolding which can be used to improve the Applications Architecture. For instance, We can use augmented reality (AR) to help students visualize abstract concepts of geometry, chemistry, or physics. It offers them interactive simulations and settings where they can use their understanding and abilities.

B. AR enhances learning opportunities

Augmented reality (AR) leverages immersive learning environments providing an entertaining approach while learning. Also, AR could provide personalized and flexible content that fits students needs, interests, and capabilities. With the aid of augmented reality (AR), students can, for instance, visit historical locations, cultural artifacts, or natural phenomena in a realistic and contextualized manner or even design their learning courses and paces based on their interests and goals [4]

C. AR expands learning opportunities

AR can overcome the limitations of time, space and resources that often limit traditional education. AR can also enable the access to experts, mentors, and peers from different locations and backgrounds. For example, AR allows students to learn anytime, anywhere using their mobile phones or connect them to collaborate and interact with other students and teachers around the world [9].

D. AR supports transversal and interdisciplinary learning

We can combine multiple subjects and fields into coherent and meaningful content for students. This incorporates the interdisciplinary learning opportunities for students. For example, students can use AR to explore the connections between science, technology, engineering, art and mathematics (STEAM) in various contexts and projects [20].

E. AR fosters students to become creative

AR also promotes students' creativity, collaboration, and problem-solving skills allows them to manipulate and explore virtual objects, environments, and scenarios. For example, students can create and share their own AR content, such as stories, games or art projects.

III. LIMITATIONS OF AUGMENTED REALITY

A. Technical issues

AR requires devices such as smartphones, tablets or headsets that support the technology and run applications. These devices may not be available or affordable for all students and schools, and may also have issues such as battery degradation, poor internet connectivity or compatibility issues [8].

B. Content quality

AR relies on the quality and accuracy of digital content that surpasses the real world. This content may not always be reliable, relevant or appropriate for learning objectives and outcomes. Teachers must carefully select and evaluate the AR content they use or create for their students [19].

C. Distraction

AR can be engaging and immersive, but can also be distracting and overwhelming for some students. AR may draw their attention away from the essential information or the teacher's instructions, or it may cause them to lose focus on the task at hand. Educators need to balance the use of AR with other methods of instruction and assessment.

D. Privacy and security

AR involves collecting and processing personal data from the users, such as their location, preferences, or behavior. This data may be vulnerable to hacking, misuse, or unauthorized access by third parties. Users need to be aware of the privacy and security risks of using AR and take measures to protect their data and identity.

E. Some prevalent limitations that have been observed in survey research

One of the AR technologies in the field of education that includes the use of the camera to get the augmented data whichever is written on the page to avoid typing and searching stuff, but the main thing is that it is only limited to some particular range of topics [8]. One of the applications was built according to use of the AR technology in the field of education using various technologies that include multimedia technology, 3D modeling, and interactive technology but it's restricted to small kids. Some only researched and put the ideas on how to deliver a realistic experience in various online platforms like for shopping where it can enhance the experience of customers by providing the best way to interact with the retailer but they haven't implemented it. One of the most common limitations was the target age group. Many applications were implemented for a specific targeted age group. There are still certain restrictions since augmented reality in education is still in its infancy. The research analysis, however, shows that majority of the limits are due to technological difficulties. As research on the use of augmented reality in education is reproduced and refined, these restrictions can eventually be addressed. The useful features of AR can start to be employed widely in all disciplines of education when the potential of AR technologies is more thoroughly investigated, and the effectiveness of teaching the students and the whole learning process will be increased [22].

IV. LITERATURE REVIEW

Augmented Reality (AR) has received a lot of attention in recent years as a technology that has the potential to change the way students usually learn. We conducted this literature review to explore the potential of augmented reality in student education by the findings from various research papers, focusing on methodology, selection criteria for survey papers, discussion of survey objectives, and technology used.

We selected research papers for this review based on the criteria to ensure the relevance of the studies on AR Applications. The primary selection criteria for survey papers included:

- 1) Publication Date: Research Papers published between 2014 and 2023 were considered to ensure the inclusion of recent and latest developments in AR technology and its applications.
- 2) Peer-Reviewed Journals and Conferences: Only papers published in reputable journals and conferences were selected to ensure the quality of the research.
- 3) Keywords: Papers that have keywords such as "augmented reality," "education," "creative learning," were prioritized.
- 4) Discussion of Survey: The survey papers that we selected, highlight different aspects of augmented reality in education:-
 - a. Pedagogical Impact: Augmented reality enhances interaction, creative thinking, student engagement with teachers and knowledge. It also promotes active learning and enables experience based learning.

b. Learning Outcomes: We studied that AR has been associated with improved learning outcomes, including in increased motivation to study, understanding of difficult concepts in a better way, and good academic performance.

c. Application Domains: Augmented reality can be applied across various domains, including science, technology, engineering, mathematics, history, and medical education.

Objectives:

The objectives of AR in student education, are summarized as follows:

- 1) To improve student engagement and interaction with teachers.
- 2) To enhance the learning outcomes and help students in understanding of difficult subjects.
- 3) To provide students with personalized and immersive learning experiences.
- 4) To provide motivation to students with the help of creative educational content.
- 5) To allow the development of essential skills in students by providing visual explanations of different subjects.

Software Technology Used: The development of AR applications for education relies on various software technologies. Based on the literature papers, We identified the software and tools that are commonly used in AR based educational applications:

- 1) Unity 3D: Unity Game Engine is a game development engine that is widely used to create 2D and 3D Games, and it also supports SDK tools for developing AR content[18].
- 2) Vuforia: Vuforia is a SD toolkit for Augmented Reality that allows developers to create marker-based AR experiences [14].
- 3) ARKit and ARCore: ARKit and ARCore are software development kits (SDKs) provided by Apple and Google, for building AR applications on IOS and Android mobile platforms.
- 4) A-Frame: A-Frame is an open-source web framework for building WebVR (Virtual Reality) and WebAR (Augmented Reality) web applications, which allows AR to work on web browsers.

V. APPLICATIONS OF AR IN STEM

- Biology class: Students can see 3D models of human organs and explore their functions and structures. They can also manipulate the models and observe the effects of different stimuli or diseases on the organs. For example, they can see how the heart pumps blood, how the lungs exchange oxygen and carbon dioxide, or how the liver filters toxins [22].
- History class: Students can scan historical images or artifacts and access additional information. They can also visit historical sites and see how they looked in different periods using AR. For example, they can see how the Colosseum was built and used in ancient Rome, how the Great Wall of China was constructed and defended, or how the Eiffel Tower was designed and erected.
- Chemistry class: Students can create virtual molecules and perform experiments. They can see the chemical reactions and properties of the molecules in real-time and get instant feedback from the AR system. For example, they can see how water molecules are formed by combining hydrogen and oxygen atoms, how carbon dioxide is produced by burning fossil fuels, or how acids and bases react with each other.
- Language class: Students can play AR games to practice vocabulary, grammar, and pronunciation. They can also interact with native speakers or cultural experts using AR avatars and learn about the culture and customs of different countries [2].

VI. FUTURE SCOPE OF AUGMENTED REALITY IN EDUCATION

The Future of AR in STEM holds exciting prospects, the future development of AR includes:

- 1) Advanced Learning Modules: As creating Educational content in AR is an iterative process, We can expect more sophisticated AR modules with labs and simulations, which will help students to learn complex topics[11].
- 2) Personalized Learning: Future AR Application can come with individual learning styles, that will provide an effective approach to teach concepts to diverse learners[6].
- 3) Augmented training and experience programs: Professional training and practice can be carried out virtually in order to get hands-on experience of technology, equipments or other application for which training is required.

VII. FINDINGS OF THE LITERATURE REVIEW

1. AR's effectiveness in recent years has led to an increase in the number of studies conducted. In particular, AR provides an efficient way to conduct research.
2. It is important to gain an understanding about the benefits of AR in the field of education and research as it is a new and emerging technology in this growing verse.
3. AR has been shown to improve student learning outcomes in various subjects, in addition to improving cognitive abilities, according to several studies [17].
4. AR technology can be further developed in education and research, as shown in the multiple reviews of research conducted in several fields.
5. According to the research, conducted in 2019, It is concluded that AR features can engage students in their learning processes and improve their visualization as well as it provides the vast opportunities to diversify the learning process with this AR is universally applicable for any level of learning which is why they are advantageous and beneficial.
6. The survey which was conducted for students, the conclusion was Teacher explanations can be improved by using the features to make students easily understand what they are taught and AR shake up's the boring environment of lectures and gives memorable and engaging experience.
7. Participants and students who expressed an interest in utilizing AR in their learning processes provided positive feedback on the utilization of the technology [13].

VIII. CONCLUSION

This survey work offers an extensive overview of the current state and future direction of AR in education. This survey focused on the papers published between 2012 and 2023. During our discussion, we covered various types of Augmented Reality (AR), explored innovative applications of AR in the field of education, examined an architecture diagram, and highlighted advantages such as personalized learning, student motivation, improved understanding, and interactive learning. We also reviewed already existing frameworks, models and various methods for designing, developing and evaluating AR applications for educational purposes. Furthermore, we emphasized emerging trends and opportunities that contribute to advancing the field of Augmented Reality (AR) in education. These include adaptive and personalized learning, collaborative and social learning, play and storytelling, as well as ethical and social considerations. We anticipate that this research paper will serve as a valuable reference for researchers, educators, and practitioners keen on exploring the potential of Augmented Reality (AR) to transform the education sector in the 21st century.

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