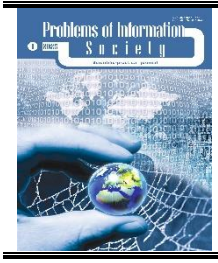

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# Measuring the importance of augmented reality applications in educational curricula

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**ABSTRACT**

Augmented Reality (AR) apps have become a powerful tool for enriching educational experiences. AR may boost student engagement and personalize the learning experience by superimposing digital information onto the actual environment, therefore bringing abstract ideas to life. Nevertheless, conducting a precise assessment of the influence of AR on student learning and determining its significance in educational curricula requires a methodical methodology. This study examines several ways for evaluating the efficacy of AR Applications in education, including both quantitative and qualitative approaches. We evaluate essential metrics, known as key performance indicators (KPIs), including engagement, learning gains, motivation, and information retention. Additionally, we assess user experience, contentment, and perceived efficacy. Furthermore, the study explores current developments in the assessment of AR, such as the use of learning analytics and educational data mining. Through the examination of various techniques, our objective is to provide a thorough framework for assessing the significance of AR Applications in enhancing educational curricula and optimizing their influence on student learning.

## 1. Introduction

There is a significant and transformative change occurring in the field of education. Immersive technology, such as AR, is revolutionizing the way we learn, breaking free from the traditional classroom setting. AR superimposes digital data on the physical environment, resulting in interactive and captivating educational encounters that have the capacity to revolutionize the field of education.

AR is an innovative technology that combines the physical and digital realms, enhancing real-world experiences by superimposing digital information onto our actual environment. AR has experienced significant growth in various sectors in recent years, and its potential in education is significant. AR integrates the real and virtual worlds seamlessly, allowing users to interact with digital elements projected onto their real surroundings. These technologies, such as smartphones, tablets, and AR glasses, use sensors and cameras to monitor the user's movement and location. AR has become more prevalent in the educational curriculum in recent years, revolutionizing conventional learning approaches and presenting new opportunities for educational practices. Technological progress is driving a substantial shift in the educational environment. AR is an advancement that has attracted significant attention due to its potential to transform education by providing immersive and

interactive learning experiences. It can make abstract concepts more tangible and increase student engagement, thereby bridging the gap between theory and practice. It offers students the opportunity to interact with the subject matter in a more captivating and meaningful way. Although there is an increasing interest in this technology, there is little conclusive scientific data about its usefulness in education. Merely integrating AR into the educational curriculum is insufficient. To comprehensively assess its influence and ascertain its genuine worth, it is important to gauge its efficacy. A comprehensive and diverse strategy is necessary to include both the measurable and subjective parts of the learning process. The conventional educational paradigm often depends on stationary texts and mechanical memorising, resulting in disinterest and restricted acquisition of knowledge. AR applications provide a possible alternative by using their capacity to animate abstract ideas and facilitate interactive learning experiences. AR enhances the learning environment by overlaying digital objects, animations, and information over the actual world. This produces a dynamic and engaging experience that promotes deeper knowledge and increases student motivation.

AR is a groundbreaking technology that has the potential to greatly impact education. AR applications can provide immersive and interactive learning experiences, which effectively engage students and improve their comprehension of intricate subjects. This study examines the importance of augmented reality applications in the educational process and the differences between augmented reality and virtual reality in classrooms, in addition to the educational benefits of augmented reality. Teachers can make informed judgements about how to use augmented reality to enhance the teaching and learning process and evaluate its impact on students' learning outcomes.

***Geolocation-based Augmented Reality:*** This approach relies on platforms or software that don't use markers, like smartphones or tablets equipped with a GPS system, to deliver digital content to learners in their real-world physical environments. This approach does not require the inclusion of additional elements in the actual educational environment. Instead, it leverages existing tracking and sensing technologies. GPS, compass, or image recognition devices.

***Augmented Reality Using AR Markers:*** Using the smartphone camera, this approach shows digital content to the learner by focusing on a specific item or target, such as a QR code or a 2D target. For efficient and cost-effective use of AR technology, the corresponding code must be accessible either on a page in the learner's curriculum or printed on A3 or A4 paper and affixed to the wall. It effectively delivers real-time instructional resources to learners using mobile devices linked to the Internet, sourced from digital learning platforms.

Applications of AR in education will evaluate a selection of programs that instructors may readily use in the classroom. They are both cost-free and very compatible with the Virtual Reality (VR) sector.

1. HP Reveal: Formerly known as Akrams, this application allows users to generate and scan images using a smartphone or tablet (iOS or Android system) to trigger certain actions or events. The technique has three options: displaying a film, providing more elucidation on a certain topic, or launching a web browser window. This technology allows for the enhancement of paper posters, photos, QR codes, and other similar media.

2. CoSpaces.edu: This program facilitates content creation by learners, allowing them to construct their own 3D models and manipulate them using custom code. This feature encourages learners to explore their creativity. Furthermore, this application enables learners to showcase their virtual ingenuity on any tangible surface in the physical realm using AR. The MERGE Cube facilitates the ability to physically grasp the virtual objects.

3. WonderScope: This program presents a digital tale using AR, which turns regular surroundings into living, interactive stories. Individuals may acquire language communication skills by posing enquiries to the story's characters and attentively listening to their responses.

4. Layer program allows users to enrich their conventional worksheets, flyers, postcards, or any other materials by including interactive multimedia elements such as video messages, websites, social networks, picture displays, music clips, and more.

5. 3D Shapes: This program teaches mathematics and geometry by allowing users to easily create geometric shapes like pyramids and solids and gradually explore more complex forms.

***The benefits of using augmented reality settings and their applications in education include.***

1. Student engagement and interest: It refers to the level of involvement and curiosity shown by students when given the chance to actively participate in the creation of instructional material. AR technologies enable the addition of curricular material, the creation of virtual worlds, and the exploration of new interests.

2. Learning environment: Incorporating AR into classrooms may enhance student engagement in the learning process. An interactive learning environment offers chances to use practical learning approaches that may heighten engagement, enrich the learning experience, and enable students to acquire and apply new abilities.
3. Comprehending material: Educators who are reluctant to use AR in education have a significant worry over the scarcity of high-quality educational material as opposed to entertainment-orientated information. Nevertheless, the present AR technology empowers instructors to independently design immersive learning experiences to guarantee their students' comprehension of curricular information.
4. Collaboration: The digital nature of AR material allows for easy sharing. For instance, a cohort of educators can collaborate with their students to consistently enhance the educational material. This collaborative learning setting fosters students' motivation to learn as they actively engage in the creation of educational content, thereby enriching the educational experience and boosting students' effectiveness.
5. Enhance memory: AR technology is a superb tool for immersing pupils in real-life scenarios and aiding in the retention of important information. As an example, rather than just displaying graphics on a projector or smart board in the classroom, a teacher may use AR technology to generate impactful and engaging narratives.
6. Sensory development: AR technology enables instructors to design lesson plans that include multi-sensory experiences. Students get advantages from immersive and augmented virtual material that incorporates experiential learning techniques, enabling students to engage in physical activities rather than passively seeing static exhibits. This strategy may enhance learners' sensory development.
7. Cost reduction: The expense associated with AR devices and equipment often serves as a barrier to the use of this technology in educational settings. Nevertheless, due to the wide range of pricing for mobile handsets and their many models, as well as the advancement of embedded technology, the procurement of the equipment required to operate AR apps has become cost-effective, feasible, and accessible to everybody. The cost-effectiveness of AR in education is growing. Furthermore, the use of AR technology has the potential to decrease educational expenses by substituting costly textbooks with augmented books and digital AR settings.

***The distinction lies in the contrast between virtual Reality and Augmented Reality.***

VR technology and AR technology exhibit significant similarities and overlap, sometimes causing misunderstanding between the two. Let's divide them. VR technology predates AR technology and is built upon virtual reality technology.

AR is a technology that superimposes digital information, such as audio, movies, and pictures, onto the actual world to augment and enrich it. Sometimes, people mistake AR for VR, as VR creates entirely artificial scenarios. We refer to the integration of these two technologies as Extended Reality (XR), causing significant transformation across several sectors. IDC projects that the AR/VR industry will grow from $16.8 billion in 2019 to $160 billion by 2023.

VR technology uses specialized instruments, such as headsets, 3D glasses, and sensors, to isolate the user from the actual world. This fully immerses the user's senses in an entirely fabricated virtual environment.

The user in AR maintains a continuous connection and awareness of the physical environment while engaging with virtual worlds created by AR technology. These virtual worlds may include many elements, such as texts, photos, audio, videos, animations, websites, or objects. The user may create three-dimensional objects or a combination of several elements using their preferred instrument, often a mobile phone, tablet, or personal computer.

Common features of both technologies include the ability to fully engage in a simulated world, travel around it using various methods, and interact with its aspects.

## 2. Related works

Currently, the world is undergoing a revolution in knowledge, science, and technology across several domains. The scope of its influence extended beyond any one domain and included all industries, with a particular emphasis on the education sector, which serves as the fundamental bedrock for the cultivation, progress, and

upliftment of societies. The use of contemporary technology has become a prominent characteristic of this period, thereby expediting its progress. Academic institutions are adapting their educational systems to align with the rapid advancements in technology and the resulting impact on the educational process. Society both influences and shapes these changes. The rapid and continuous advancement of technology requires educators to constantly seek out new instructional techniques that align with the evolving nature of technological progress. It facilitates the acquisition of knowledge for the learner.

AR technology is a contemporary concept that has recently gained prominence. Information technology introduces this technology, which integrates virtual reality into the real world. AR technology refers to a system that integrates virtual reality surroundings with actual environments using specialized techniques and procedures. AR technology is a crucial tool for updating education and preparing students for the future. AR is a very effective educational setting that stimulates pupils to critically examine scientific truths and both real and imaginative notions.

AR is a form of virtual reality technology that involves integrating virtual objects into the real world. This creates the illusion that these virtual objects exist in the physical world while also providing additional information that may not be directly perceivable by users. Users struggle to discern and differentiate these virtual objects using their abstract faculties. The objective is to establish a system that eliminates the ability to distinguish between physical reality and the virtual items integrated into it using this technology. The use of this technology in education offers several benefits and advantages, particularly when instructing complex topics in some academic disciplines, since it introduces an additional dimension. Compared to previous teaching approaches, this approach is novel in its use of sound, visuals, three-dimensional (3D) shapes, and video as fundamental components in the simulation process that underlies the creation of AR.

The use of contemporary technology is crucial in enhancing the pedagogical approaches for teaching science and streamlining the vast array of topics it encompasses, thus facilitating students' comprehension in a systematic and practical manner. We accomplish this by employing modern software and communication methods in the teaching of this subject matter. The utilisation of technology, particularly in scientific disciplines, effectively addresses various challenges in information exchange among participants in the educational process (such as teachers and students, and students with one another). It enhances active engagement among learners, captures their interest, and alleviates the instructional burden on teachers. Furthermore, it effectively tackles the issue of extensive curricula and courses.

Given that the gifted and talented category is seen as a valuable national resource that should be harnessed for the betterment of both individuals and society, it is necessary to use distinct teaching approaches for these kids to equip them with the critical thinking skills required to successfully complete assignments. This research aims to investigate the effects of implementing AR programs on academic performance, considering the significance of using technological advancements in the educational context.

AR is a potent technology that enhances learning and participation in education. Nevertheless, precisely assessing its influence requires a methodical methodology. This study examines the current body of research on quantifying the efficacy of AR applications and puts up a structured model for assessing their significance in educational programs.

## 2.1. Measuring the Impact of AR Applications

### 2.1.1. Quantitative Methods:

KPIs that are often used to judge how well AR apps work include engagement (measured by time spent on task, level of interaction, and completion rates), learning gains (measured by pre- and post-test scores, quizzes, and assessments), motivation (measured by surveys and interviews), and knowledge retention (measured by long-term follow-ups) (Akçayır & Akçayır, 2017; Wu et al., 2022). Learning analytics and educational data mining are tools that examine student interaction data to detect trends, forecast performances, and customize learning routes (Sung et al., 2016). AI-powered assessment refers to the use of technologies that use Artificial Intelligence (AI) to provide immediate feedback and customise examinations according to the specific requirements of each student (Huang et al., 2020).

**2.1.2. Qualitative Methods:**

User experience and satisfaction: Usability tests, satisfaction questionnaires, and perceived effectiveness surveys assess user experiences and perceptions of the AR application's influence on teach (Wu et al., 2022). Interviews and focus groups often serve as methods of gathering information through direct interaction with individuals or groups. (Garzón & Acevedo, 2019) argue that these methodologies provide more profound understanding of student attitudes, motives, and learning experiences.

**2.2. Emerging Trends in AR Measurement**

Integration of VR: The fusion of AR with VR results in enhanced learning settings, enabling students to engage with virtual worlds and interact with virtual items (Vargas et al., 2020). Individualised learning is the focus: Researchers are developing assessment tools to collect data for tailored learning experiences tailored to individual needs (Shaghaghian et al., 2022). Ethical considerations: As the development of AR technology progresses, it is imperative to confront ethical concerns related to data privacy, fairness, and inclusivity (Carreon et al., 2017).

The percentage of AR/VR application in education: AR and VR have become a part of the education sector and are changing the conventional mode of teaching. Research shows that AR/VR applications are utilized in education at every level, and the majority of those applications dedicate themselves to engagement and learning outcomes. These technologies provide interactive, real-world learning removed from the traditional classroom in a controlled, safe environment, simplifying even the most complex subject (science, history, medicine, and engineering).

The percentage of AR/VR applications in training: AR/VR training applications now account for a significant portion of the overall AR/VR use cases in various industries, especially in high-risk or complex environments where traditional training is inadequate. We can train VR to set for pilot, surgeon, machinery operator etc. AR applications enable support and troubleshooting on the job. Adoption rates vary by industry and region, but AR/VR training is picking up steam based on statistics proving its ability to increase knowledge retention, cut training costs and improve productivity. As shown in Fig.1

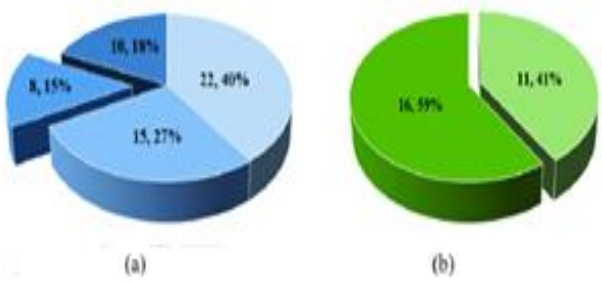


**Fig. 1.** (a) The percentage of AR/VR applications in education. (b) The percentage of AR/VR applications in training

**2.3. Potential of AR in Education:**

Multiple studies have emphasized the potential advantages of AR in education. Akcayir and Akcayir (2017) conducted a comprehensive analysis of 68 papers on AR in education. They found that AR offers significant benefits, including heightened learning motivation and improved efficacy of the learning process. Furthermore, (Wu et al., 2022). highlighted the ability of AR to customize learning experiences by adapting information and activities to suit the specific requirements and learning preferences of each student.

Quantitative data analysis involves systematically examining numerical data to uncover patterns, relationships, and trends. It is commonly used in research to test hypotheses, draw conclusions, and make predictions. The primary methods of quantitative data analysis include:

1. Descriptive Statistics:

Provides a summary of data using measures like mean, median, mode, range, variance, and standard deviation. Visual tools like histograms, bar charts, and pie charts are used to represent data distribution.

2. Inferential Statistics:

Draws conclusions about a population based on a sample. Techniques include hypothesis testing, confidence intervals, and significance testing (e.g., t-tests, chi-square tests, and ANOVA).

3. Correlation Analysis:

Examines the relationship between two or more variables. Common measures include Pearson's correlation coefficient (for linear relationships) and Spearman's rank correlation (for non-linear relationships).

4. Regression Analysis:

Explores the relationship between dependent and independent variables to predict outcomes.

Techniques include linear regression, multiple

regression, and logistic regression for binary outcomes.

5. Factor Analysis:

Identifies underlying patterns or structures in data by grouping related variables. Often used in survey research to reduce dimensions or simplify data.

6. Cluster Analysis:

Group's data points with similar characteristics into clusters for classification or pattern recognition. Common in market segmentation and customer profiling. Visualizations for quantitative data analysis methods are shown in Fig.2.

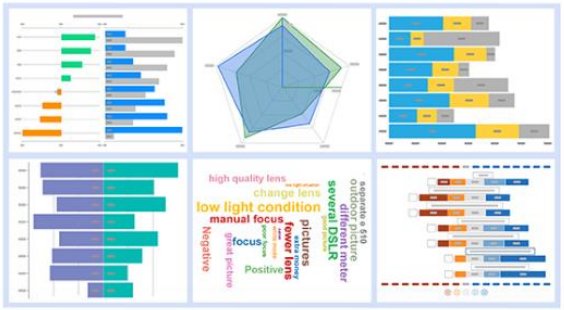


**Fig. 2.** Visualizations for Quantitative Data Analysis Methods

### 2.4. Measuring the Impact of Educational Technologies:

Assessing the efficacy of educational technology, such as AR, requires a methodical and meticulous methodology. We have used conventional approaches like pre- and post-test designs to evaluate the progress of student teaching (Dunleavy & Mitchell., 2014). Nevertheless, these techniques may not comprehensively include the intricate consequences of AR; hence, they require more sophisticated and multidimensional methodologies.

Positive Impact of Educational Technology on Higher Education:

Educational technology has revolutionized higher education, fostering significant positive impacts across various dimensions (Fig. 3). Here are the key benefits:

1. Enhanced Accessibility: Educational technology enables access to quality education for students worldwide, regardless of geographical constraints. Online platforms, such as MOOCs (Massive Open Online Courses), provide opportunities for learning to individuals in remote areas or those unable to attend traditional classrooms.

2. Personalized Learning: Adaptive learning systems use data analytics to tailor educational content and pace to individual students' needs, enhancing understanding and retention. This personalized approach accommodates diverse learning styles and paces.

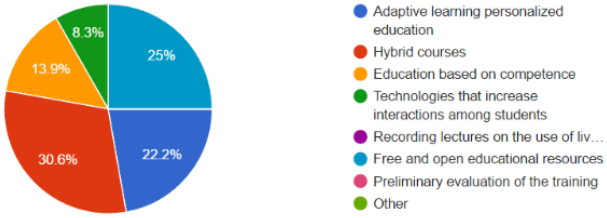


**Fig. 3.** Positive educational technology impact on higher education

**Purpose of the work**

The aim of the current work is to explore and evaluate the functionality and importance of AR applications in the building of educational curricula. Exploring how AR technologies have impacted student engagement, learning outcomes, and pedagogical practices, this study seeks to inform educators, curriculum designers, and policymakers about the potential of AR as a transformative tool in education. Furthermore, this paper intends to highlight the level of challenges and opportunities related to offering AR into different educational contexts and provide evidence-based recommendations on how to integrate AR effectively.

**Problem statement**

Technological advancements have significantly impacted the educational landscape, prompting even educators to to switch their teaching methods to applying technology in their teaching (Cen et al., 2020). Out of this technology, AR has shown its users a new way of building immersive and interactive learning experiences Despite the potential of AR to wound student engagement, facilitate deeper understanding, and accommodate various learning styles, the use of AR in educational curricula is limited and has not been consistent.

One such concern is the lack of empirical evidence and in-depth studies that determine the significance and effectiveness of AR applications in educational environments. Challenges often arise for educators and policymakers seeking to understand how AR fits into upper-level curriculum goals, enhances learning outcomes, and considers different levels of technological accessibility (Han et al., 2022). Moreover, highlighting challenges that could hamper proper implementation, including a lack of resources, lack

of teacher training, and student adaptability to AR technologies, should be observed.

This study aims to fill these gaps by assessing comprehensively the relevance of AR applications in educational curricula and discussing their advantages, challenges and overall contribution to contemporary education. It is hoped that this can lay out evidence-based guidance for the strategic implementation of AR within the classroom.

## 3. Materials and methods

AR has become a potent instrument in education, providing immersive and interactive learning experiences that have the potential to transform teaching and learning. Precisely assessing the significance of AR apps is essential to comprehending their genuine worth and maximizing their influence on educational achievements (Sung et al., 2016). A systematic strategy that incorporates both quantitative and qualitative techniques is necessary for this.

### 3.1. Quantitative Methodologies

a) Key Performance Indicators (KPIs):

Engagement: Monitor the duration of engagement with AR activities, the percentage of tasks completed, the degree of involvement, and the frequency of use.

Learning gains: Evaluate the acquisition of information and the development of skills by conducting pre- and post-test assessments, quizzes, assignments, and performance activities.

Objective: Employ surveys and interviews to assess student enthusiasm for AR technology, their inclination to acquire knowledge, and their self-reported level of confidence in the subject matter.

User Experience: Administer user satisfaction surveys and usability tests to evaluate the user-friendliness, functionality, technical proficiency, and overall efficacy of the AR application.

b) Learning Analytics and Educational Data Mining:

Use learning analytics technologies to examine student interaction data with AR materials, detect trends, forecast performance, customize learning paths, and adapt interventions.

Employ educational data mining methods to analyze extensive datasets of student attributes, learning activities, and AR usage patterns to reveal hidden correlations and their influences on learning results.

c) Standardized Tests and Assessments:

Use the AR application to assess students' performance on standardised examinations related to the taught subject matter and compare the results with traditional learning methods.

Create and execute tests specifically designed for AR, considering the unique learning opportunities provided by this technology.

a) Observations:

Monitor the conduct and social interactions of students while using the AR application to get a deeper understanding of their level of involvement, cooperation, and ability to solve problems.

Record instructor methodologies and classroom interactions to analyze AR integration with current instructional approaches and its influence on classroom administration.

b) Interviews and Focus Groups:

Perform individual interviews and focus groups with students and instructors to get comprehensive feedback about their experiences with the AR application.

Investigate student perspectives on AR technology, their comprehension of the subject matter, and their general contentment with the educational encounter.

Gain insight into teachers' viewpoints about the efficacy of AR in promoting learning, developing lesson plans, and handling technology in the classroom.

c) Case Studies:

Perform comprehensive case studies on distinct AR applications in various educational environments to assess their influence on student learning and instructor methodologies.

Examine the specific elements and surrounding circumstances that influence the success—or lack thereof of incorporating AR into educational settings.

### 3.2. Problem solving

This study employs a holistic problem-solving approach that not only evaluates AR technologies for educational purposes but also looks for design-based solutions to overcome the complexities involved with AR integration into educational learning contexts (Albouys et al., 2018). The procedure is as follows:

Conducting Empirical Research:

Data will be collected through surveys, interviews, and case studies with educators, students, and institutions that have embraced AR technologies. Such a pragmatic method can help reveal tangible results, user experiences, and

obstacles while deploying it.

Comparative Analysis:

Illustrate the value added by comparing traditional teaching methods with AR-enhanced approaches. This is done to understand the strengths and weaknesses of AR technology and also in what scenarios it works very well.

Fostering Collaboration:

To support long-term adoption, the study emphasises the importance of collaboration between technology developers, educators, and administrators. Partnerships and professional networks are encouraged to share best practices and promote innovation in AR-based learning.

### 3.3. Emerging Trends

1. AI-powered assessment: Employ AI algorithms to analyze student data in real time, deliver personalized feedback, and customize examinations to meet individual requirements (M. Al Qudah et al., 2024).

2. Integration of VR: Investigate the synergistic impact of combining AR and VR in educational environments to enhance immersion in learning experiences.

3. Ethical considerations: Discuss ethical concerns related to privacy, data security, and possible bias in algorithms to guarantee the appropriate use of AR in the field of education.

### 3.4. Factors to Consider when Choosing a Methodology

1. Study objectives: Precisely articulate the specific goals of the study and the variables you want to quantify.

2. Target audience: Select strategies suitable for the demographic characteristics, cognitive preferences, and technical proficiency of the pupils.

3. Resource and time limitations: Choose approaches that are achievable given the available resources and time limits.

4. Curriculum alignment: Verify that the selected methodologies effectively assess the influence of the AR application on the precise educational goals outlined in the curriculum.

## 4. Discussion

Despite its many potential benefits, integrating AR into educational settings also presents certain challenges. Technological issues and the need for teacher training are among the challenges. It is imperative that we prioritize overcoming these problems and investigating the most efficient methods of incorporating AR in a variety of educational settings. The future implications of AR in education are vast and transformative (Lampropoulos & Keramopoulos, 2022). AR has the potential to revolutionize the traditional classroom model by offering immersive, interactive learning experiences that cater to different learning styles. Students can engage with complex subjects in a more intuitive manner, fostering deeper understanding and retention of information. Additionally, AR can enhance collaboration among students and teachers by allowing real-time feedback and personalized learning paths. As AR technology continues to advance, the possibilities for its application in education are only expanding. However, maximizing its educational benefits requires addressing challenges such as ensuring equitable access to AR resources and addressing privacy concerns. Overall, the integration of AR in education holds promise for creating a more engaging and effective learning environment.

## 5. Conclusion

With the ability to provide learning experiences that are both immersive and participatory, AR has the potential to completely transform the educational system. Teachers are coming up with creative ways to integrate AR into their instructional strategies, which is making learning more interesting, accessible, and efficient. This is a direct result of the ongoing advancement of technology. Given the current advancements in AR applications, it is highly likely that the seamless integration of digital and physical worlds will shape the future of education. This will offer students a dynamic and significantly enhanced learning environment. As AR technology continues to advance, we may anticipate the use of many more cutting-edge applications in educational settings across the globe.

The integration of AR technology in education has proven to be a promising and innovative approach to enhancing the learning experience for students. Through the use of AR applications and tools, educators can create immersive and interactive learning environments that cater to individual learning styles and preferences. This study employed a methodology that involved conducting a comprehensive review of literature, analysing data, and gathering insights from educators and students who have implemented AR in the classroom. The results

indicate that AR has the potential to improve student engagement, motivation, comprehension, and retention of information. By leveraging AR technology, educators can create dynamic, personalized learning experiences that cater to the needs of students in the digital age. As technology continues to evolve, the possibilities for AR in education are endless, paving the way for a more interactive and engaging educational landscape.

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