

# SYSTEMATIC LITERATURE REVIEW: USE OF AUGMENTED REALITY AS A LEARNING MEDIA: TRENDS, APPLICATIONS, CHALLENGES AND FUTURE POTENTIAL

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## Abstract

This article conducts a systematic literature review (SLR) focusing on the application of Augmented Reality (AR) as an educational tool. The review process, guided by SLR and PRISMA methodologies, included steps such as identification, screening, eligibility assessment, inclusion, and data analysis, utilizing tools like Publish or Perish 8 and NVIVO 12 Plus. An initial search on Scopus produced 800 articles, which were subsequently narrowed down to 59 relevant studies. These were analyzed with NVIVO 12 Plus according to specific topics. The results indicate that AR effectively enhances students' academic achievement, interest, motivation, and participation across various subjects such as science, mathematics, languages, and engineering education. However, challenges include hardware and software limitations and insufficient technical training for teachers. AR holds great potential for improving learning experiences, particularly for students with special needs. Future developments should focus on affordable software and adequate teacher training to expand AR's educational use. Further research should explore AR in vocational education to better understand its specific requirements.

**Keywords :** Augmented Reality, learning media, Systematic Literature Review

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Received: 22-05-2024 | Revised: 22-06-2024 | Accepted: 07-08-2024  
DOI: <https://doi.org/10.23887/janapati.v13i3.78825>

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## INTRODUCTION

Currently, technological developments are progressing rapidly. Compared to previous years, technology continues to develop rapidly and presents various innovations. Technological advances have changed the way work becomes more efficient and faster. Technology has now become an inseparable part of everyday life, and one sector that benefits from technological advances is education. The integration of technology has introduced innovation into the teaching and learning process, enhancing both the effectiveness and dynamism of education.

The use of technology in the learning process has become crucial, especially during the widespread Covid-19 pandemic. We are all forced to depend on technology to conduct educational activities. Although for the millennial generation, this may not be so difficult because they are already used to new technology, for some more senior educators, keeping up with technological developments may be a challenge.

In the learning context, there are several concepts that not all students can understand just by verbal explanation from the teacher. Some students need visual assistance to better

understand the material being taught. Technological advancements in education have generated various tools and media that significantly contribute to enhancing the effectiveness of achieving learning objectives. Augmented Reality is now increasingly essential in education. For example, Augmented Reality (AR) technology can improve student understanding with a visual and interactive approach. Its advantages in use and available tools support its integration in education. AR integrates the real world with the digital world [1], [2], [3], [4].

Utilizing Augmented Reality as an educational medium offers students direct interaction and hands-on experiences. This enhances learning engagement by merging the virtual world with physical reality, thereby stimulating students' imaginations. Interactive Augmented Reality allows students to see the situation directly, helping them understand the learning concepts presented by educators [5], [6]. This is in line with the opinion of [7] that the application of Augmented Reality technology in education aims to assist students in gaining a new perspective or developing new skills.

Augmented reality improves students' readiness, interest, motivation and self-confidence, as well as academic results. Learning media is key, especially for conceptual and abstract material, and with augmented reality, abstract events can be turned into concrete through artificial intelligence programs [8], [9],[10].

Although technology is advancing rapidly and making AR software and hardware more accessible and affordable [11], not all teachers are ready or have the ability to take advantage of it. The use of augmented reality (AR) in education remains limited, primarily serving as a supplementary tool for interactive learning in schools [12]. Some students and teachers stated that hardware and software limitations increase content loading times in AR applications. In addition, the availability of adequate technology is a problem, because not all students have access to the necessary devices [13]. This is an obstacle in implementing the use of augmented reality in the learning process.

According to research [7], in the future, experts in the field of augmented reality (AR) need to develop software that is more affordable to apply in school environments. Apart from creating AR objects, you also need guidelines and guidelines for their use. Schools should train teachers in the design and use of AR and set up teaching technology support centers. Training for educators on enhanced learning technologies is needed to create engaging virtual environments. This allows teachers to direct students according to the curriculum and their abilities [3].

This study employs the Systematic Literature Review method by gathering articles based on specific keywords. The goal is to gain insight into the use of Augmented Reality as a learning medium. The findings are expected to provide an understanding of AR as an educational tool. The researchers posed four key research questions: 1) What are the trends in the effectiveness of AR in education? 2) How is AR integrated into various subjects within educational settings? 3) What challenges and obstacles arise in using AR as a learning medium? 4) What is the future potential of AR in enhancing the learning experience?

**METHOD**

Augmented Reality (AR) based teaching design refers to the planning and development of learning processes that utilize AR technology to increase teaching effectiveness and interactivity. The Systematic Literature Review method was applied in this research to explore the application of Augmented Reality in an educational setting. The SLR method is often used as a method to

gain in-depth understanding in a research field [14], [15].

To achieve the research objectives, there are several research questions that focus on the structure and organization of studies on AR in learning. There are six steps in this inclusion and exclusion process: 1) Using the Publish or Perish 7 application to search for literature in Scopus with API Key; 2) Selection of articles from the Scopus database; 3) Explore articles related to the application of Augmented Reality in education; 4) Limiting the publication period from 2019 to 2023; 5) Choose articles written in English; and 6) Concentrate on scientific articles, excluding papers, conference proceedings, book chapters, and dissertations.

Literature from Scopus is accessed via the Publish or Perish 7 application. The filtering process is carried out based on titles, abstracts and keywords that are relevant to the research theme without being too general. From this search, 800 articles from Scopus were found, the details can be seen in table 1 below.

Table 1. Article findings from the Scopus database via Publish or Perish 7

No	Keyword	Amount
1	Augmented Reality	200
2	Use of Augmented Reality	200
3	Augmented Reality as a Learning Media	200
4	Augmend Reality in Educatio	200
	Total	800

The next article is presented systematically, covering all variables that meet the previously established criteria. This study uses the PRISMA technique in four article search steps: identification, review, assessment for eligibility, and inclusion. The search process using the PRISMA flow diagram is illustrated in Figure 1. From the Scopus database, 800 articles were found via the Publish or Perish 7 application. Articles that met the criteria were selected, reducing the number to 494 articles after 306 articles that did not meet the criteria were deleted. Of the 494 articles, after checking for similar articles, 341 articles remained and 153 similar articles were eliminated. Next, 103 articles relevant to the topic were selected. After further review of the titles, abstracts, keywords and content of the articles, the 59 most relevant articles were selected.

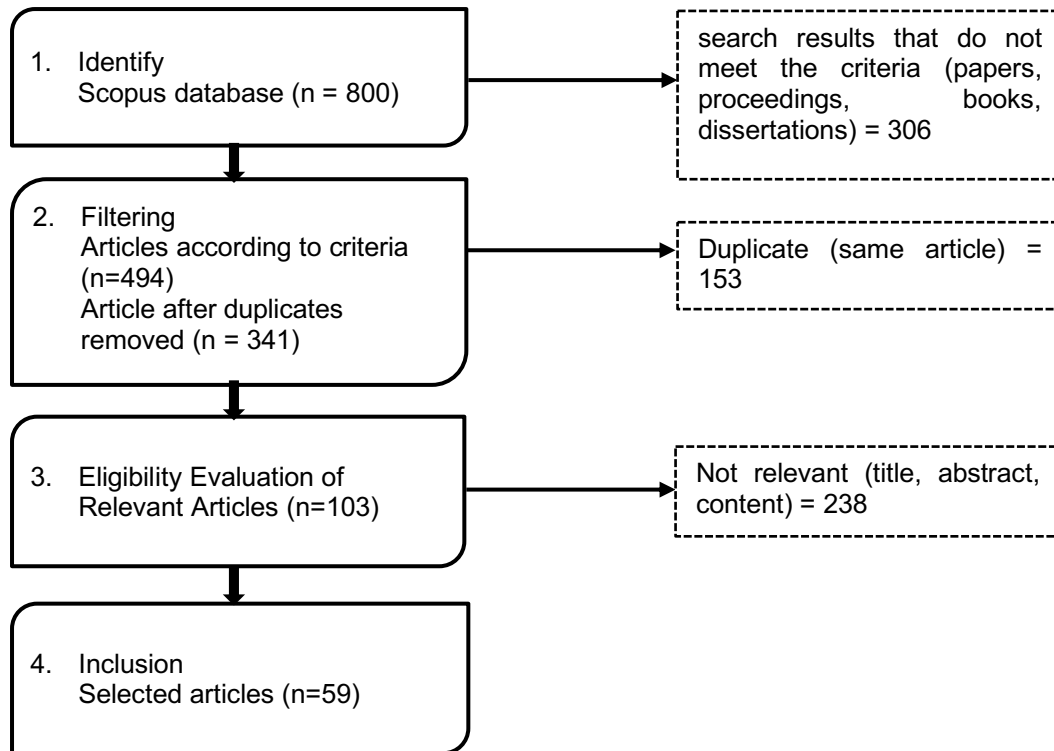


Figure 1. Systematic Review Prism Diagram [14], [16], [17]

## RESULT AND DISCUSSION

After obtaining data from the use of NVIVO 12 Plus, it is essential to display information from 59 articles based on research, subjects, methodology used, country and its relevance to the four research questions, namely trends in AR effectiveness, application of AR in educational unit subjects, obstacles and challenges in its development, as well as the potential of AR as an educational tool.

After the coding process was applied to existing sources, trends, patterns and variations of words that frequently appeared were found,

as shown in Figure 2 below. The aim of this analysis is to identify the words that appear most frequently in the articles reviewed in this study. Its main function is to discover key themes, important terms, and trends related to the utilization of Augmented Reality (AR) in education. By analyzing the frequency of frequently occurring words, insight can be gained into the focus of current research, aspects frequently discussed, and areas that may require further research.



Figure 2. Word Frequency

### **Trends in the Effectiveness of Using AR in Education**

Currently, augmented reality (AR) is gaining popularity in various areas, including education. AR is known for its ability to realistically present multimedia content in real environments via web devices such as mobile phones and tablets, enabling flexible access anywhere and at any time. In addition, AR can also address financial and spatial constraints associated with scientific and technological laboratory equipment and facilities [18] by implementing an AR-based additional learning environment (ARLE) [19]. The use of AR can increase interactivity in learning, allowing feedback in the form of ideas, arguments, data interpretation, explanations, and problem solving [20].

Most of the articles reviewed stated that augmented reality (AR) has demonstrated positive impact [21] and is effective in increasing learning achievements [22], [23], [24]. AR has the ability to attract attention, motivate, and provide real visual representations of learning material, thus requiring a high level of reasoning and imagination to understand these concepts. Successful implementation of AR has also been shown to contribute to academic achievement [25] and student performance in academic environments [26].

Research results show that integrating augmented reality technology in education 4.0 is very effective and can improve students' understanding in vocational high schools [27], increase students' spatial learning activities [28], [29], [30], increase encouragement for students' cognitive engagement [31], [32], increasing focus [33], increasing interest and motivation to learn in more depth [34], [35], [36], ncreasing teacher creativity [37], and increasing the effectiveness of student learning in real-life situations [38]. Even for autistic children, AR can increase their level of attention and focus [39]. Studies also found that the higher the motivation (including self-confidence, attention, contentment, and relevance) [40], the higher the retention of acquired knowledge [41].

Additionally, AR significantly enhances individual learning skills, with subsequent improvements observed in social skills, physical skills, and life skills for individuals with special needs [42]. In an educational setting, the use of AR can transform the school environment into a more technology-oriented space, with the potential to integrate simulations into real-world contexts, particularly in education. Students find the learning process more engaging, and AR technology has the potential to enrich their

educational experience [43], and can even contribute to the preservation of cultural artifacts [44].

Augmented reality (AR) can be applied in various models, including mobile multiplayer AR [45], AR with voice input [46] which can evoke positive emotions such as enthusiasm, enjoyment, and curiosity, as well as the use of AR flashcards for vocabulary learning [47]. From the review of the articles carried out, we can see a trend in the use of AR where AR can embed virtual messages into educational materials, allowing three-dimensional models to be integrated with learning resources, allowing students to read books while interacting with three-dimensional character models [48]. AR can also be combined with simulation applications for effectiveness in influencing learning of related content [49]. AR implementation acts as a tool to strengthen concepts that students have mastered well [50], [51]. AR applications enable students to visualize abstract concepts through three-dimensional virtual objects, thereby achieving deeper understanding and ultimately, achieving better academic performance [52]. Through the use of a smart glasses-based AR system, the conventional laboratory learning setting was successfully transformed from a separate resource format into an integrated presentation format with live data visualization [53].

### **Application of AR in Subjects in Education Units**

The application of augmented reality (AR) in chemistry education is highly compelling due to its considerable potential. Integrating AR with text and images in learning aligns with the concept of multiple external representations and cognitive multimedia learning theory. Research indicates that using AR to teach topics such as stereochemistry, carbonyl chemistry, and pericyclic reactions can alleviate both intrinsic and extraneous cognitive loads [54]. Apart from that, AR technology has also been used in learning Arabic vocabulary in elementary schools through the Arabic-Kafa application. With this application, students can learn to recognize Arabic letters and vocabulary through 3D images, thereby creating a new and interesting learning experience [38]. The application of AR has also been applied in teaching reading comprehension for elementary school students [51]. AR is also applied in combined STEM and arts subjects for elementary school students [34], [43] through the Gamification Augmented Reality in STEM (GAR-stem) application [55]. AR technology,

particularly in high school STEM education, enables students to explore, practice, and engage with STEM content without concerns about financial or ethical issues, such as the high costs of materials or the risk of harm to animals [49].

Studies also show that the use of AR is more effective than video-based teaching, and has a better effect in learning difficult motor skills in Physical Education lessons for elementary school students [48]. Students using AR show a substantial improvement in achievement and learning motivation compared to those using traditional multimedia science learning methods at the elementary school level [56]. The application of AR is also observed in the instruction of English as a Foreign Language (EFL) [57], [58], as well as in the learning of Chinese characters using AR-based games in elementary schools [32].

The application of AR is also seen in mathematics learning at the elementary school level [36], [59] and junior high school [21], [60], such as in material on the geometry of solid objects with an AR application called GeoC [50]. Studies also show that the use of AR-based applications is more effective than web-based applications in improving students' understanding of the basic principles of geometry [61]. Apart from that, AR has also been applied in history learning [24], science with solar system material, and other topics for junior high school students [52]. The use of AR can also help improve abstract thinking skills in physics learning for high school students [35], [62].

AR has also been implemented in phonics literacy courses for children with autism [39], as well as in basic number learning for students with special disabilities, especially for the LINUS program in elementary schools [63]. The incorporation of 3D AR media featuring Grebeg Pancasila has introduced a tangible dimension to the Grebeg Pancasila ritual, enhancing character education and local wisdom [64]. AR is also relevant for landscape architecture education as site visits have historically been an important element of pedagogical approaches in the field [65].

The use of Augmented Reality (AR) as a learning medium in pencak silat courses has been proven to be valid, practical and effective for university level students [66]. Apart from that, AR has also been used in the field of Engineering Education [18], electronics laboratory skills [19], as well as in Science and Engineering courses [23]. The implementation of AR in the computer network device course allows students to better understand concepts

such as the shape and visualization of the names of computer network devices that resemble the original shape, as well as information related to each device [67]. AR also helps in visualizing abstract Physics concepts for Electrical Engineering students [68]. Compared to the use of handouts or videos, the use of AR in textile and intimate accessories learning provides a more satisfying learning experience for students [30]. Finally, the implementation of AR-based interactive multimedia in teaching earth and rock structure science has been conducted for students in elementary school teacher education programs [20].

### **Barriers and challenges in using AR as a learning medium**

The increasing use of digital media demands adaptation from stakeholders in the education sector. Good quality distance education can match the quality of face-to-face learning in the classroom [27]. However, the necessary preparations are still challenging from a logistical perspective because they require special equipment such as 3D printers, which take a long time to print the model [69]. Few teachers directly implement this new medium in the classroom due to teachers' lack of familiarity with creating digital 3D models [70], so only a few students benefit from AR-enriched offerings. In addition, overcrowded curricula and a lack of development resources in schools make it difficult to conduct experiments. This issue is compounded by the limited availability of educational applications with sufficient learning content [43].

The most frequently cited drawbacks pertain to the complexity of using AR, particularly when it involves children. As a novel technology that engages multiple senses, AR can often be quite intricate, especially for those who are not well-versed in technology. Teachers also experience technical difficulties when using AR in their classrooms. This may be due to a lack of technical training for some teachers to manage AR systems, lack of experience in education, and lack of institutional support which may limit their use in educational settings [26], [71]. Therefore, initial training is needed so that teachers are able to design and implement practices with augmented reality in teaching [72].

There are a number of challenges that can hinder educational progress in using AR, such as the availability of appropriate technical infrastructure and high costs in content development, which impact both educators and students [18]. Challenges related to technology and devices also arise, including the large size of applications that require devices that are

capable of handling them and have high-quality cameras [24]. AR applications are also susceptible to physical factors such as lighting, output quality, and camera quality [52]. Such technical limitations or technological glitches, such as camera lens sensitivity or GPS location recognition, may negatively affect students' motivation to engage or maintain their engagement in learning activities. The need to have special equipment and students' concerns regarding the suitability of these methods to teaching and learning practices can also negatively impact or even reduce the overall learning experience [31]. Challenges also arise internally from students, where they may be distracted by AR animations and may not follow the instructor's guidelines [47].

**The future potential of AR as an educational tool to enhance the learning experience**

Augmented Reality (AR) holds significant potential to revolutionize education by motivating students to develop their own AR content, which can enhance higher-order thinking. AR mobile applications have great potential in the teaching and learning process, especially for students with Linus (literacy and numeracy screening) disabilities, because it can motivate them to understand lessons, particularly in fundamental mathematics, such as assessing and performing calculations with the aid of visual media [63]. The use of AR applications on smartphones is leveraged for concept demonstrations and digital experiments, enabling the visualization of complex theoretical topics such as the material of the Earth-moon system in the form of 3D animations or turning them into cheap and accessible digital experiments [73]. AR can also enrich education as an effective teaching tool, especially when 3D model visualization becomes the focus of learning. For example, incorporating AR-based experiences into advanced

biochemistry modules could enhance the teaching of university-level content on protein structure and function [69]. Across various educational fields, AR is having a significant impact, including in the Arts, Humanities, Health, and Wellness. The implementation of AR systems has been shown to enhance students' academic performance. AR provides three key features: real-world annotation, contextual visualization, and vision-haptic visualization, all of which contribute to long-term memory retention [26]. Moreover, the creation of location-based and narrative-driven AR games for foreign language instruction demonstrates significant behavioral, cognitive, and emotional engagement, as well as positive attitudes toward learning English as a foreign language (EFL) [74].

Since AR can be accessed anywhere and provides virtual experiences, it is an appropriate solution to address potential challenges in engineering education [18]. Students with disabilities may also experience significant benefits from engagement in AR-based learning [75]. The educational potential of AR technology is enormous, as its benefits include student cognitive acceleration, improved self-management, and increased engagement in practice-based activities [76]. The potential application of AR is also evident in teaching life skills crucial for daily activities, requiring minimal human intervention, thereby enhancing both academic and functional skills for individuals with special needs [42]. In the future, the potential of AR will not only be limited to improving scores or attitudes, but also on deeper learning concepts and strategies [60], and on students' capacity to actively engage in the learning process by creating AR applications related to the subject matter, using straightforward programs [51].

**Table 2. Findings of 59 Selected Articles from the Scopus Database**

No.	Research Question	Study
1	Trends in the effectiveness of using AR in education	[18], [19], [20], [21], [22], [23], [24], [25], [26], [27], [28], [29], [30], [31], [32], [33], [34], [35], [36], [37], [38], [39], [40], [41], [42], [43], [44], [45], [46], [47], [48], [49], [50], [51], [52], [53]
2	Application of AR in subjects in educational units	[18], [19], [20], [21], [23], [24], [30], [32], [34], [35], [36], [38], [39], [43], [48], [49], [50], [51], [52], [54], [55], [56], [57], [58], [59], [60], [61], [62], [63], [64], [65], [66], [67], [68]
3	Barriers and challenges in using AR as a learning media	[18], [24], [26], [27], [31], [43], [47], [52], [69], [70], [71], [72]
4	The potential of AR as a learning media in the future to improve the learning experience	[18], [26], [42], [51], [60], [63], [69], [73], [74], [75], [76]

## CONCLUSION

Augmented Reality (AR) has great potential to change education in positive ways. AR not only increases student engagement and enriches the learning experience, but can also improve conceptual understanding, cognitive skills, and engagement in hands-on activities. Although there are technical and logistical challenges in using AR, such as scarcity of technical infrastructure and high costs of content development, its benefits in increasing learning effectiveness are significant. Additionally, AR also has the potential to enhance inclusivity in education, particularly for students with disabilities. With proper training and effective content development, AR has the potential to be a significant tool for enhancing educational quality across various fields and levels. Future research should investigate further the application of Augmented Reality (AR) within Vocational Education, focusing on the advancement of AR technology in vocational settings and addressing the needs of vocational students and educators.

## ACKNOWLEDGMENT

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