

Application of Augmented Reality (AR) in vocational education: A systematic literature review

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ABSTRACT

Augmented Reality (AR) is a technology that combines two-dimensional and or three-dimensional virtual objects into a real environment and then projects these virtual objects in reality in real time. Through this AR technology, users can see virtual objects added to the real world with contextual information. In education, AR has been widely used to complement the standard curriculum. Text, graphics, video, and audio can be superimposed into the student's real-time environment. This article aims to examine how the application and impact of the use of AR in vocational education. The Systematic Literature Review (SLR) method is used to identify, study, evaluate, and interpret Augmented Reality in vocational education. Research data were identified using the SLR method with the help of the PRISMA 2020 form. Article collection was carried out on the Science Direct database. There were as many as 454 articles. After being selected using inclusion and exclusion criteria, the data used were 14 articles. The study results reveal that AR is applied in learning as an innovative learning medium, a new approach to learning to improve students' understanding of knowledge and skills and provide a concrete learning experience. The integration of AR in education has the impact of increasing students' understanding and learning experience, promoting positive attitudes, making the learning process fun and interesting, and learning efficiency.



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INTRODUCTION

This rapid development of technology makes most students still learn by listening to the subject matter delivered by the teacher or by just reading books, which often feel boring for students (Pranoto & Panggabean, 2019). With the rapid development of technology today, learning methods, as usual, are not fun nowadays (Nuralim & Aswan, 2019). The integration of technology in the learning process has emerged a lot to create fun but effective learning (Sandoval-Henríquez & Badilla-Quintana, 2021). One of them is the use of augmented reality in learning. In its development,

augmented reality is used as a learning medium to explain information to be accepted and provide interaction in the learning process (Herbert et al., 2021).

Augmented Reality (AR) is a technology that combines two-dimensional and or three-dimensional virtual objects into a real environment and then projects these virtual objects in reality in real-time (Krüger et al., 2022). This AR technology allows users to see virtual objects added to the real world with contextual layers of information (Ibáñez & Delgado-Kloos, 2018). In education, AR has been widely used to complement standard curricula. Text, graphics, video, and audio can be superimposed into a student's real-time environment, providing different experiences to students (Belani & Parnami, 2020). Augmented reality learning media in schools can significantly impact students' ability to understand learning concepts (Aprinaldi et al., 2019).

Chen et al. (2017) mentioned that Augmented Reality (AR) is a technology that utilizes digital products or information superimposed on physical objects or environments to create a hybrid reality where virtual objects and real-world environments can interact meaningfully to enhance the learning experience. In its application, AR uses various technological tools such as multimedia, 3D modeling, real-time tracking and registration, intelligent interaction, sensors, and others (Y. Chen et al., 2019). A significant advancement in virtual reality is the capacity to manipulate artificial world objects by using controllers such as Oculus Touch. Its capabilities allow students, for example, in education, to experience and acquire knowledge by engaging with objects in virtual environments more engagingly (Elmqaddem, 2019).

The main principle of AR is to incorporate virtual information generated by computers, such as text, images, 3D models, music, videos, and so on, into the real world through computer simulation. With such significant technological advances, AR makes it possible to manipulate objects in the virtual world using controllers or devices such as Oculus Touch. This allows students in an educational context to engage and gain knowledge by interacting with objects in a more engaging virtual environment.

AR in educational contexts allows students to experience practical learning and can increase participation in direct interaction with relevant objects or content (virtually). For example, in vocational education, AR can let students view and manipulate 3D objects virtually, perform practical simulation tasks, and gain immersive experiences through immersive learning environments. Thus, AR can enhance students' learning experience by incorporating virtual elements into their physical world.

Based on the background that the researcher has presented, this study aims to explore information on how AR can be used specifically in vocational learning, including the types of relevant AR applications and how this technology can be optimized to increase the effectiveness of vocational learning. This research also explores the impact of using AR in vocational learning in terms of student motivation and engagement, conceptual understanding, practical skills, and improved academic achievement.

RESEARCH METHOD

Systematic literature reviews are methods of identifying, evaluating, and interpreting all research related to a particular topic that is available and relevant to answer a particular research question, topic area, or phenomenon of interest by transparently and including all evidence and assessing its quality (Kitchenham & Charters, 2007). This article was created using the SLR method to examine the application of augmented reality in vocational education. At the beginning of the review, the research question is spelled out as a goal that must be answered. The database selected for the search is then indicated, as well as search keywords and criteria followed for evaluating and selecting studies. Finally, we introduce the publication at the end of the process (Zhao et al., 2021). The PRISMA flowchart for this research can be seen in Figure 1.

The systematic review methodology ensures that a comprehensive and systematic approach is followed in selecting and analyzing the articles. By searching for specific terms in the title, keywords, and abstract, the researchers aimed to identify articles that specifically address the topic of augmented reality in education. This approach helps to narrow down the focus and relevance of the articles included in the review. Using the Science Direct database as the data source ensures

access to various scholarly articles and publications in various disciplines. The researchers have utilized specific search strings to retrieve articles most relevant to the topic under investigation.

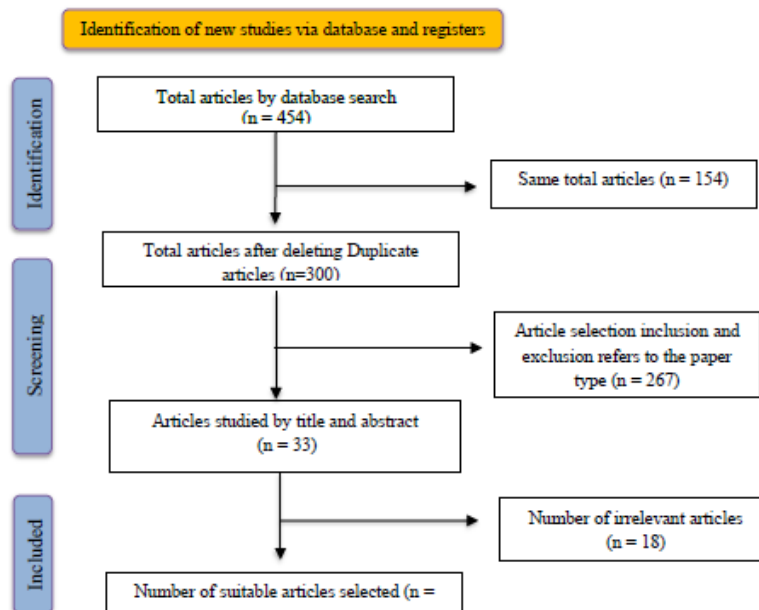


Figure 1. PRISMA Flowchart for this Research

This systematic approach helps to provide a comprehensive overview and analysis of the existing literature on augmented reality in education. Overall, by utilizing the Science Direct database and employing specific search strings, this literature review article aims to gather relevant and up-to-date research on the application of augmented reality in education, learning, and teaching.

Inclusion and exclusion criteria should be applied in any study. Inclusion and exclusion criteria are established to select relevant studies to obtain answers to the research questions asked. The study selection process is an iterative and incremental process divided into several stages with different activities carried out. The search was conducted to obtain articles on the research results on augmented reality in education. The initial search yielded 454 articles. The inclusion and exclusion criteria in this study can be seen in Table 1.

Table 1. Inclusion and Exclusion Criteria

No.	Inclusion	Exclusion
1	Research relating to augmented reality for educational or vocational learning purposes.	Research related to virtual reality or mixed reality.
2	Research articles published between 2018 - 2022.	Research articles not published between 2018 - 2022.
3	Research articles are written in English.	The article was written not in English.
4	Open access to research articles or can be downloaded the full version.	Research articles cannot be downloaded for the full version.
5	The research follows the appropriate structure and research methods.	The article is not a literature review, review, and bibliometric research

FINDINGS AND DISCUSSION

The literature review results will be presented in the form of answers or findings relevant to the research questions posed. The researcher will organize and present the findings systematically, based on certain themes or concepts that emerge from the literature analysis. Quotes and references from the articles reviewed will support these answers.

QA 1. How is the Application of Augmented Reality in Vocational Education?

Table 2 describes the application of augmented reality based on the selected articles.

Table 2. Table of Applications of AR in Vocational Education

No.	Journal Article Title	Application of AR in Vocational Education
1.	Augmented reality supported product design towards industry 4.0: A teaching factory paradigm	Application of advanced visualization techniques in product design
2.	Enhancing the attractiveness of learning through augmented reality	To improve communication and collaboration skills
3.	Impacts of an augmented reality-based flipped learning guiding approach on students' scientific project performance and perceptions	Augmented Reality (AR) based learning to develop flipped learning systems and test the effectiveness of the proposed approach
4.	Potentials of augmented reality in training	As an innovative learning medium that demonstrates several use cases and optimizes education and training to meet the needs of digitalization more successfully
5.	Improving the quality of teaching and learning in classes by using augmented reality video	Improving students' learning experience and improving their understanding of complex issues by incorporating mobile augmented reality (AR) applications into sewing workshops where threading tasks are performed to facilitate better learning
6.	Augmented reality experiment in higher education, for complex system appropriation in mechanical design	To visualize design or simulation models and apply real system manipulations, related to various representations, especially for students who do not have technological skills
7.	An augmented reality collaborative product design cloud-based platform in the context of learning factory	For product design, customization, and visualization with the use of AR will also be developed to gather useful insights about the skills and competencies acquired by the participants
8.	Assimilating disruptive technology: A new approach to learning science in engineering education	Elaborating the understanding of Ohm's law using AR technology. A marker-based AR application called AROhm has been developed that can make students learn in an augmented Hands-on way to give them a new and concrete learning experience
9.	Increase the interest in learning by implementing augmented reality: Case studies studying rail transportation	Application of augmented reality technology in the learning process. The case study used in this paper is the implementation of augmented reality in the subjects studied related to railway technology.
10.	Designing and evaluating a highly interactive augmented reality system for programming learning	To find a solution to make the concept of programming more real.
11.	Designing a framework for collaborative mixed reality training	To propose methods to extend collaborative extended reality (XR) applications to various platforms to support collaborative learning, but also other types of applications such as collaboration and remote maintenance
12.	Practical development of engineering simulation-assisted educational AR environments	Engineering simulation with AR/VR education is still challenging and requires expertise from various disciplines throughout technical development. Case studies were developed to teach chemical engineering concepts using the liquid soap synthesis process during the COVID-19 Pandemic
13.	Leveraging augmented reality to teach probability and sampling: Computers & education	Explore ways for students to learn basic statistical reasoning skills authentically and interestingly
14.	Augmented reality application in vocational education: A case of welding training	AR applications are designed and developed to provide welding knowledge and skills and training

Table 2 shows the application of augmented reality in vocational education from selected journals. From the table, it can be concluded that six articles show the balance of AR in education which generally aims to improve students' knowledge, skills, and learning experiences in a more interesting and differentiated way (Agrawal & Pillai, 2020; Iftene & Trandabăț, 2018; Mourtzis et al., 2020; Sharma & Mantri, 2020; Solmaz et al., 2021; Yip et al., 2019). In its use in schools, five articles show AR is integrated into the learning process as an interactive learning media (Mourtzis & Vlachou, 2018; Pranoto & Panggabean, 2019; Scaravetti & Doroszewski, 2019; Sorko & Brunnhofer, 2019; Yi-Ming Kao & Ruan, 2022). At the same time, the other three articles show the application of AR that complements new approaches to learning (Chang & Hwang, 2018; Conley et al., 2020; Kostov & Wolfartsberger, 2022). The application of AR in learning can improve students' learning experience through interactive learning media applied to various learning methods.

QA 2. How does the use of Augmented Reality in Vocational Education Impact?

Table 3 describes the impact of using augmented reality in vocational education based on the selected and shortlisted articles. From the table, it can be concluded that the impact of AR implementation in education is very positive. The use of AR in learning can improve student understanding and provide concrete learning experiences (Mourtzis & Vlachou, 2018; Scaravetti & Doroszewski, 2019; Sharma & Mantri, 2020), encourage positive attitudes (Chang & Hwang, 2018; Conley et al., 2020; Iftene & Trandabăț, 2018; Kostov & Wolfartsberger, 2022; Mourtzis et al., 2020; Yi-Ming Kao & Ruan, 2022), the learning process becomes fun and interesting (Pranoto & Panggabean, 2019) and efficiency in learning (Mourtzis et al., 2020; Solmaz et al., 2021; Sorko & Brunnhofer, 2019; Yip et al., 2019). It can be concluded that the impact of the application of AR in vocational education is to provide concrete learning experiences to students, the learning process becomes interesting and fun, positive attitudes arise, and efficiency in learning occurs.

Table 3. Impact of the Use of AR in Vocational Education

No.	Journal Article Title	Impact of AR Usage
1.	Augmented reality supported product design towards industry 4.0: a teaching factory paradigm	By using Augmented Reality, Teaching Factory participants have real-world experience in scaling the insights of the products they are designed and can interact with. the assembly of the final product is carried out 10% faster
2.	Enhancing the attractiveness of learning through augmented reality	The use of augmented reality to improve communication and collaboration skills between children, especially children with autism, and game-based student evaluations in various teaching areas, allows for a stress-free testing environment
3.	Impacts of an augmented reality-based flipped learning guiding approach on students' scientific project performance and perceptions	AR-based flipped learning is not only beneficial for students in terms of improving their project performance, but also increases learning motivation, critical thinking tendencies, and the self-efficacy of their group
4.	Potentials of augmented reality in training	The integration of AR technology in training and further development leads to significant cost reductions
5.	Improving the quality of teaching and learning in classes by using augmented reality video	These findings are consistent with the post-test value and the time it takes to learn the threading task. Some feedback items demonstrate higher learning efficiency with the use of AR video
6.	Augmented reality experiment in higher education, for complex system appropriation in mechanical design	Assistance in follow-up procedures (handling operations in practice sessions or assembly/disassembly operations). Here, AR is used as an educational support tool and introduces students to technology relevant to the industry.
7.	An augmented reality collaborative product design cloud-based platform in the context of learning factory	The proposed application allows the utilization of different platforms to suit easier implementation in any industrial environment at a low resource cost. Thus, breaking the boundary between the device utilization of similar platforms, the application's proposed collaborative design combines most of the existing devices in a more realistic collaboration experience
8.	Assimilating disruptive technology: A new approach to learning science in engineering education	Theme-based projects facilitate students to think outside the curriculum, and industrial projects help them to adjust to industry expectations. Results from the review of the technical expertise and documentation of the expert committee are enhanced. Competent students are allowed to continue their 6th-semester project as an institute research project (IRP) The vision of the IRP is to shape students with industry expectations and push their technical skills toward product development
9.	Increase the interest in learning by implementing augmented reality: Case studies studying rail transportation	The application of augmented reality technology in learning materials helps the learning process and increases the impressive and fun factor in the learning process and makes the learning process more interesting. The application of Augmented Reality in learning materials provides more information about the object being studied, information about the shape, and texture, and provides more visualization of the object.
10.	Designing and evaluating a highly interactive augmented reality system for programming learning	Para students in the high interactive group achieve a more positive experience in assembling puzzle cards to learn to program AR-based instruction, especially in the high interactive AR mode, helping students improve their programming performance, get higher learning motivation, reduce their cognitive load, and obtain a high level of technological acceptance
11.	Designing a framework for collaborative mixed reality training	Gain useful insights into collaborative training and serve as a good starting point for future projects
12.	Practical development of engineering simulation-assisted educational AR environments	Engineering stimulation with AR can facilitate versatile and sustainable educational tools for use in an active learning environment
13.	Leveraging augmented reality to teach probability and sampling: Computers & education	AR also had a positive impact on participants' perceptions of engagement. Thus, it will be strategic to continue to focus on the relationship between learning acquisition and engagement for research ideas involving the design and implementation of AR
14.	Augmented reality application in vocational education: A case of welding training	The final product is a mobile application that uses AR marker-based which can be used on Android phones

CONCLUSION

The application of augmented reality in education is an example of how schools are addressing the ever-evolving technologies in the industry and ensuring students, especially from vocational education, compete with the competencies available in the job market and set by the industry. Traditional learning carried out in the classroom is no longer fully effective in conveying information and materials to students. It is considered a method that does not contribute to productivity and instills learning motivation in students. Meanwhile, the application of virtual learning defines the variety of technology and supports educational strategies in promoting independent learning for students, increasing their productivity, and engaging them with effective learning. In addition to extensive online information, students can explore unlimited valid resources and introductions to online learning that contribute to improved collaboration between students and overall improve clear ways of communication and increase self-confidence. Innovations in learning strategies with augmented reality integration introduce simple learning and flexible time and location engagement. These strategies are available for distance learning and require only low investment. Overall, modern strategies of a combination of technologies such as augmented reality implanted in the classroom promote better and more conducive learning than traditional learning and thus improve student achievement academically and intellectually.

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