Hipkin Journal of Educational Research | e-ISSN 1234-5678 & p-ISSN 1234-5678
Volume 1 No 3 (2024) 263-274

Hipkin Journal of Educational Research
http://ejournal-hipkin.or.id/index.php/hipkin-jer/

Application of augmented reality in education

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ABSTRACT

The development of character and human resource quality can be improved by sustainable educational innovation in teaching methods and media, so educators must create an attractive and informative learning environment. One of these innovations is using augmented reality (AR) in education, which can produce generations of creative, innovative, and competitive individuals. This study uses the literature review (literature review) analysis method by analyzing the urgency of applying augmented reality (AR) in education in the era of society 5.0. This study aims to examine the development of AR technology in Indonesia's education world and its impact on improving the quality of education in Indonesia both now and in the future. The study results show that AR has the potential to improve the quality of education in Indonesia. AR can increase students' motivation and interest in learning, improve students' understanding of learning concepts, and make the learning process more interactive and engaging. In addition, AR can help prepare young people for a dynamic future.

ARTICLE INFO

Article History:
Received: 16 Aug 2024
Revised: 7 Nov 2024
Accepted: 15 Nov 2024
Available online: 3 Dec 2024
Publish: 30 Dec 2024

Keyword:
augmented reality; education era 5.0; educational technology

Open access
Hipkin Journal of Educational Research is a peer-reviewed open-access journal.

ABSTRAK

Pengembangan karakter dan peningkatan kualitas sumber daya manusia dapat ditingkatkan dengan inovasi pendidikan yang berkelanjutan dalam metode dan media pembelajaran, maka penting bagi pendidik untuk menciptakan lingkungan belajar yang menarik dan informatif. Salah satu inovasi tersebut adalah dengan menggunakan augmented reality (AR) ke dalam pendidikan yang dapat mampu menghasilkan generasi individu yang kreatif, inovatif dan kompetitif. Penelitian ini bertujuan untuk mengkaji perkembangan teknologi AR dalam dunia pendidikan di Indonesia dan dampak yang dihasilkan dari penggunaan AR dalam meningkatkan kualitas pendidikan di Indonesia baik sekarang maupun di masa depan. Penelitian ini menggunakan metode analisis kajian pustaka (literatur review) dengan menganalisis tentang urgensi penerapan augmented reality (AR) pada pendidikan di era society 5.0. Hasil penelitian menunjukkan bahwa AR memiliki potensi untuk meningkatkan kualitas pendidikan di Indonesia. AR dapat meningkatkan motivasi dan minat peserta didik untuk belajar, meningkatkan pemahaman peserta didik tentang konsep pembelajaran, dan membuat proses pembelajaran lebih interaktif dan menarik. Selain itu, AR dapat membantu mempersiapkan generasi muda untuk masa depan yang dinamis.

Kata Kunci: *pendidikan 5.0; realitas tertambah; teknologi pendidikan*

How to cite (APA 7)
Trikotama, R. M. A., Nurrohman, M. N., & Hutajulu, D. K. (2024). Application of augmented reality in education. *Hipkin Journal of Educational Research, 1*(3), 263-274.

Peer review
This article has been peer-reviewed through the journal's standard double-blind peer review, where both the reviewers and authors are anonymised during review.

INTRODUCTION

Education has undergone evolution and development over time, especially in terms of its elaboration with other aspects of life. One aspect that has greatly influenced the field of education is the use of technology and information. Technology, information, and communication have developed rapidly. Currently, all aspects of human life depend heavily on technology, especially with the advancement of the internet in this era. This is supported by data from a survey conducted by the Indonesian Internet Service Providers Association (APJI), which indicates that the number of internet users in Indonesia has increased to 215 million, up from 210 million in 2022. Of course, the high use of technology and the internet among the public poses its own challenges in improving digital technology literacy, especially in the field of education. According to Nisrina (2021), advances in information and communication technology have not only increased access to education through e-learning but also the use of various online platforms available today. (Nisrina, 2021).

The development of information technology has enhanced competencies in the field of education. Learning in the 21st century is expected to help students develop skills in learning and innovation, including critical thinking for problem-solving, creativity and innovation, as well as communication and collaboration skills (Ashari, 2023). Currently, various types of platforms can be used to support the teaching and learning process, including ubiquitous learning (u-learning), Augmented Reality (AR), Virtual Reality (VR), mobile learning (m-learning), games, gamification, and learning analytics (Alzahrani, 2020). One of the platforms currently being discussed is the use of AR. AR is a technological innovation that can transform virtual objects, both two-dimensional and three-dimensional, into part of the real environment that is projected simultaneously. AR, a technology that utilizes digital products or information integrated into physical objects or environments, creates a hybrid reality where virtual objects and the real-world environment can interact significantly to enhance the learning experience (Chen et al., 2017). AR can be accessed via smartphones using the Android operating system, as Android supports the digital learning strategies currently used by teachers (Retnaningtiyas, 2021).

The use of AR as a learning medium can be a solution to make the learning process more interactive and engaging, thereby improving students' critical thinking skills. AR has several advantages in the context of education, specifically as an educational medium that significantly impacts the learning process. AR in learning can eliminate dependence on lesson schedules and classrooms, allowing students to study learning materials wherever and whenever they want (Ahsan et al., 2020). The primary principle of AR is to insert virtual information generated by computers, such as text, images, 3D models, music, and videos, into the real world through computer simulation. Significant technological advances in AR also enable the manipulation of objects in the virtual world using controllers or devices such as Oculus Touch. Thus, in the context of education, students can be actively involved and gain knowledge by interacting directly with objects in a more engaging virtual environment. In addressing challenges and enhancing the competitiveness of human resources globally, AR media has become an attractive innovation to utilize. The use of AR-based learning media can increase the motivation and interest in science learning among junior high school students. This effectiveness is due to the novel and engaging nature of AR media, which successfully captures students' attention during the learning process (Ardani, 2023).

Several studies on Augmented Reality (AR), particularly those related to education, have been conducted in recent years. AR technology plays a crucial role in enhancing the quality of learning in vocational schools. It can help develop both cognitive and practical skills that are relevant to the industrial world. Through the use of AR, students can enhance their competitiveness in an increasingly demanding job market (Kusandi, 2024). AR can be used to introduce technological developments to children, showcase tourist attractions and hometowns, and provide access to more realistic information, as 3D objects can be displayed in AR. As a result, children can be motivated to learn more about technology and its application

in everyday life (Permana et al., 2022). Lastly, AR also possesses characteristics that align with the current era of technological revolution, as it provides interactive and independent learning media. This makes AR a suitable solution for education in the era of Industrial Revolution 4.0 and Society 5.0. In its implementation, AR can also enhance the practicality and effectiveness of student learning, thereby contributing to improved learning outcomes (Tasrif et al., 2020).

The development of AR technology in the Indonesian education sector has drawn the attention of researchers to explore further current AR developments and their impact on enhancing the quality of education in Indonesia, both now and in the future. This distinguishes this study from previous studies. In addition, the literature study method was employed to describe and interpret relevant information related to the current use of AR media in educational implementation and its potential future impact.

LITERATURE REVIEW

Education that focuses on character development and improving the quality of human resources requires continuous innovation in learning methods and media. Teachers, as planners and evaluators of learning activities, play a central role in designing learning environments that align with current developments, including the needs of students (Rahmawati & Suryadi, 2019).

Augmented Reality (AR)

Augmented Reality (AR) is a 3D technology that integrates the real and virtual worlds simultaneously, projected onto an Android camera (Mustaqim & Nanang, 2018). AR is also defined as a technology that integrates two-dimensional and/or three-dimensional virtual objects into the real physical environment and projects those virtual objects in real-time (Krüger et al., 2022). In AR technology, there are three basic characteristics: the combination of the real and virtual worlds, real-time interactions, and the representation of objects in the form of three-dimensional (3D) models (Midik et al., 2023; Shelton, 2002). The process of creating a mathematical representation of a three-dimensional surface of an object using specific software is called Three-Dimensional Modeling (3D), also known as meshing. The result of this modeling is known as a 3D model, which can be displayed as a two-dimensional image through a process called 3D rendering. A 3D model is represented as a collection of points in three dimensions, connected by various geometric entities such as triangles, lines, curved surfaces, and others (Guntur et al., 2020).

AR has several advantages, namely: AR can show parts of a field or spatial structure in vertical or horizontal positions; AR can show changes in the shape or position of an object; AR can show changes in the shape of a flat field or spatial structure based on the direction of rotation; AR can show the shape of a spatial structure or the relationship between parts of a building; AR can show the shape of a building (Guntur et al., 2020). Several components are required for the creation and development of ARy applications, including both software and hardware. The minimum hardware required to implement this AR technology is a camera, a screen, and a processor. The camera captures the real world, which the processor then processes and interprets. The processor adds virtual objects to the real-world video captured by the camera. The results of the previous stage are then displayed on the screen. The display can be a smartphone screen or a laptop screen (Sungkono et al., 2022). In the world of education, AR has been widely used to complement standard curricula. Text, graphics, video, and audio can be superimposed onto the real-time environment of learners, providing them with a different experience (Belani & Parnami, 2020). AR learning media in schools can have a significant impact on students' ability to understand learning concepts (Aprinaldi et al., 2019). Dewi & Anggraeni (2020) mention that the use of AR in learning can be facilitated through smartphones with the Android operating system, as this platform supports the strategies employed by teachers in the current digital era (Dewi & Anggraeni, 2020).

Education in the Era of Society 5.0

Currently, technological developments are influencing and are essential in every aspect of life, including the world of education, which presents new opportunities and challenges for education today. The Society 5.0 era is a paradigm shift that has a significant impact on various aspects, one of which is education. This change utilizes the application of technology in learning. The implemented technology can help students prepare for various dynamic changes that may occur in the future. The current Society 5.0 era prioritizes the development of artificial intelligence (AI), the Internet of Things (IoT), robotics, and other technologies that can enhance human productivity and quality of life (Skobelev & Borovik, 2017). In this context, humans are considered the center of technological development, capable of creating a harmonious relationship between humans, the environment, and technology. Society 5.0 can create human resources ready to face and master various challenges by implementing the innovations of the Industrial Revolution 4.0 into the social order, as stated by Ruskandi in his book entitled "*Transformasi Arah Tujuan Pendidikan di Era Society 5.0*". In the context of Society 5.0 in education, learning is centered on the effective and efficient use of technology to develop various solutions to social and environmental problems that arise (Sakiinah et al., 2022).

Learning that is designed and used in the era of Society 5.0 produces results that emphasize the development of creativity, social skills, leadership, and empathy in students. These abilities are essential for today's students because they equip them with the competencies necessary to address future challenges. Society 5.0 refers to individuals who play a role in addressing various social challenges and problems by utilizing innovations that emerged in the era of Industrial Revolution 4.0, centered on technology (Martini et al., 2019). To address these challenges, educators and human resources professionals today must possess strong teaching skills and be competent in both technology and education. Preparing students to face various challenges and problems in the future is not solely the responsibility of educators; it also requires the support of technology, such as the internet, computers, mobile devices, and other digital tools that enable students to learn online, utilize online resources, and engage with developed learning applications.

In this regard, the government needs to pay attention to and fulfill its obligation to facilitate the equitable integration of technology into the learning process. Technology can help provide access to learning for students, especially in remote areas, and improve the quality of learning by offering various features and facilities that support the learning process, such as simulations, animations, and videos. Therefore, with this technology, students can access learning materials online through various digital platforms. This is important so that all students, including those in remote areas, can benefit from technology in learning. With adequate technological facilitation, it is hoped that the quality of education in Indonesia can be improved, thereby producing superior human resources who are ready to face the challenges of the times.

Education in the era of Society 5.0 is directed towards the development of technology in learning. Technological innovation in education can prepare future generations to face the challenges and opportunities of this century, creating a more progressive and sustainable society. Technological innovation in education offers numerous benefits, including personalized and adaptive learning, broad and flexible access to education, interactive and in-depth learning experiences, enhanced collaboration and communication, the development of digital skills, and readiness to face various changes (Legi, 2023). To prepare the younger generation for an uncertain future, the education system must adapt and innovate to ensure that every individual possesses the skills, knowledge, and values needed to succeed and contribute meaningfully in an increasingly connected and digital society.

Utilization of Augmented Reality in Education in the Era of Society 5.0

In the era of Society 5.0, education plays a vital role in enhancing the quality of human resources and fostering a creative, innovative, and competitive generation. One way to achieve this goal is by incorporating AR into education (Fricticarani et al., 2023). AR is a technology that manipulates reality by displaying objects in 3D, creating the illusion that users are viewing something in the real world. Here are key points regarding the application of AR in education in the Society 5.0 era:

1. Interactive learning: AR allows students to interact more with concepts and learning materials. Using AR, students can see and experience the phenomena or concepts of their choice more clearly and engagingly.
2. Personalized learning: AR allows teachers to tailor learning to individual students' needs and abilities. This allows students to learn the material more efficiently and effectively.
3. Practical Training: AR helps learners develop practical skills in various fields, such as aviation, helps them develop technical skills, and helps them experience real-world situations.
4. Developing Soft Skills: AR allows learners to develop soft skills such as communication, collaboration, and critical thinking by exposing them to situations where they interact with virtual objects in real-world environments.
5. Coordination between education and industry: The government must be able to coordinate education and industry to enable university and postgraduate graduates to incorporate technology into their teaching and learning activities (Marlina et al., 2023; Harahap et al., 2023).

In the context of language education, AR can also be used to enhance conceptual understanding and create a more engaging and informative learning environment. For example, AR can be utilized to develop learning modules on plane geometry that help eighth-grade students gain a deeper understanding of selected concepts.

The introduction of AR in education requires an educational approach that fosters a generation of creative, innovative, and competitive individuals, as well as teachers with strong digital literacy and creative thinking skills. Technological devices capable of displaying comprehensive learning materials, such as iOS- or Android-based mobile devices, also play a crucial role in implementing AR in education.

METHODS

In writing this article, the analytical method employed is a literature review, utilizing the appropriate steps for conducting a literature review. A literature review is typically defined as the activity of reviewing research conducted by collecting and synthesizing previous studies. By integrating findings and perspectives from many individuals, this review can then be used to develop a theory and address the strengths and weaknesses of previous research (Snyder, 2019). The steps for the literature review are explained in **Figure 1**, which outlines six key steps: choosing a topic, searching for literature reviews, developing arguments or opinions, reviewing existing literature reviews, critiquing literature reviews, and writing the results of the analysis that have been carried out.

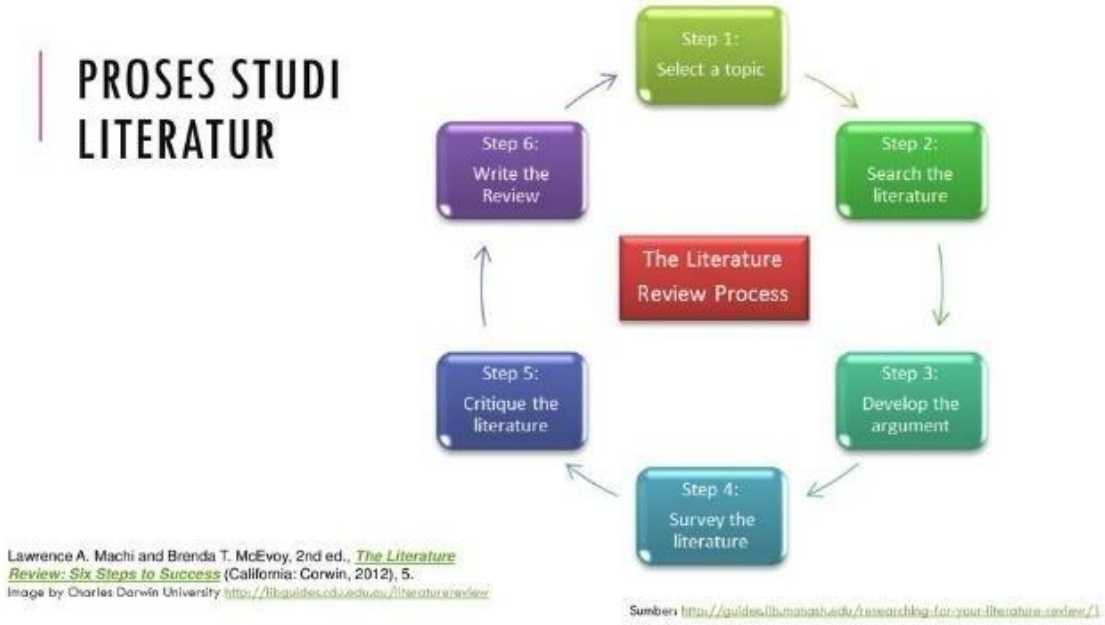

Figure 1. Literature Review Process
Source: Machi & McEvoy dalam "The Literature Review: Six Steps to Success"

This article focuses on a literature review analysis of Augmented Reality (AR). Another focus of the literature review is the application of AR media in education within the context of Society 5.0. Second, the topic of this study will lead to an explanation of the impact and urgency of implementing AR in education, especially in the current era of digital technology and the internet. Finally, the study will be concluded and linked to supporting theories to create a new understanding. The stages or procedures followed in writing this article are shown in the image below.

RESULTS AND DISCUSSION

Application of Augmented Reality (AR) in Education in the Society 5.0 Era.

The focus of education in the Society 5.0 era is the development of technology in learning. This innovation can prepare future generations to face the challenges and opportunities of this century, building a more progressive and sustainable society. Augmented Reality (AR) is one of the most exciting technological innovations for educational applications. AR manipulates reality by displaying objects in three dimensions, giving users the illusion of viewing something in the real world. This allows learners to interact more with ideas and learning materials, which can help them sharpen their critical thinking. **Table 1** below is a summary of the literature that discusses the use of AR in the world of education in the Society 5.0 era:

Table 1. Literature Review Articles

Writer	Article Title	Article Summary
(Amalia et al., 2024)	Eksplorasi Dunia Satwa Melalui Pelatihan *Augmented Reality* bagi Guru KB IT Ratu Kalinyamat Jepara.	The technological revolution in the digital era and Society 5.0 has made it crucial for teachers to enrich their learning methods. AR has been proven to improve the knowledge and skills of not only students but also teachers. One teacher at KB IT Ratu Kalinyamat Jepara responded positively. They found that AR increased their knowledge and interest in teaching animal exploration.

Writer	Article Title	Article Summary
		Learning using AR is believed to improve early childhood English skills from 40% to 90%.
(Saraswati et al., 2023)	Pengembangan Media Edukasi Pengenalan Profesi Bagi PAUD Melalui *Augmented Reality* Menggunakan Assemblr.	Technological developments have impacted the evolution of society in various fields, including education. AR is an innovation that can create hybrid learning by combining real and virtual objects. AR-based educational media books have been created and proven to influence how students understand and interact with information, shape new perspectives on technology, and stimulate interest in specific career fields. Going forward, these learning media can be further developed to create even more effective learning experiences.
(Rachim et al., 2024)	Pemanfaatan *Augmented Reality* Sebagai Media Pembelajaran Terhadap Keaktifan Belajar Siswa Dalam Pendidikan Modern	By presenting information visually in a physical environment, augmented reality technology has been proven to increase student learning engagement. This is because AR can make abstract concepts more concrete and easier to understand. More specifically, AR can increase student interest in learning, thereby opening the door to more enjoyable and practical learning experiences. In the future, training for students and ensuring the availability of technological infrastructure must be guaranteed to create a more interactive and relevant learning experience for students.

Source: Research 2024

According to research, the use of AR in learning can not only increase students' motivation and interest in learning, but also improve their understanding of learning concepts, as well as enhance teachers' knowledge and skills (Tarsidi et al., 2024). Through learning using AR, teachers' interest and exploration of teaching materials can increase (Amalia et al, 2024). Educators in the era of Society 5.0 must possess strong teaching skills and be competent in educational technology. If this happens, it is hoped that the quality of Indonesian education will improve (Martini et al., 2019). In addition, AR-based educational media can influence the way students understand and interact with information, form new perspectives on technology, and stimulate interest in specific fields of work (Nurdiyanto et al., 2024; Saraswati et al., 2023; Supriyanto et al., 2023). In the future, students can increase their competitiveness in an increasingly competitive job market (Kusandi, 2024).

The use of AR in learning can also eliminate dependence on traditional class schedules and physical classrooms, allowing students to access learning materials at any time and from any location they choose. Utilizing AR as a learning medium can help enhance students' critical thinking skills and make the learning process more interactive and engaging. This can serve as a solution to educational challenges in Indonesia. AR media is one of the most exciting innovations to address global challenges and improve human resource competitiveness. The use of AR-based learning media can increase middle school students' motivation and interest in learning science. Its effectiveness lies in the innovative and engaging features of AR media, which successfully capture students' attention throughout the learning process (Puspitarini & Marlena, 2022; Ardani, 2023).

The Impact and Urgency of Implementing Augmented Reality (AR) in Education

The application of AR in education has yielded numerous benefits that can be used to develop education in Indonesia. Beyond these numerous benefits, AR implementation will undoubtedly also impact the

education system and structure. **Table 2** presents a summary of the literature discussing the impact and urgency of AR implementation in education.

Table 2. Literature Review Articles

Writer	Article Title	Article Summary
(Fauzziyah, 2019)	*The potential of augmented reality to transform education into smart education*	AR can be considered for learning because it has advantages: printed materials can be enriched with digital media information, enhance real-world perception, allow students to experiment and acquire practical skills, increase motivation, and foster educational development. However, AR also has disadvantages, including potential technical issues such as device failure, slow internet connections, or software issues. AR educational applications also require ongoing development, a process that can be time-consuming and resource-intensive.
(Akbar & Djakariah, 2023)	*Opportunities and Challenges for Using Augmented Reality-Based Learning Media in Chemistry Education in the Era of Society 5.0.*	AR can enhance students' understanding of abstract chemistry concepts in this article, through three-dimensional (3D) visualizations and interactive experiences. However, AR faces challenges such as uneven hardware availability and connectivity in educational settings. Furthermore, educators' AR skills also need to be taken into consideration. Creating quality AR content requires significant time, resources, and specialized design skills.
(Fitriani, 2024)	Transformasi Pendidikan Pada Era Revolusi Industri 4.0. dan Masyarakat 5.0.: Tantangan dan Solusi	The world of education is undergoing fundamental changes driven by digital technology, artificial intelligence, and robotics. In this context, adapting education and educators is key to facing this era. Challenges such as low literacy rates, shifting learning paradigms, and access to technology require attention. Furthermore, strategies that must be employed include improving digital literacy, learning innovation, and enhancing educator and teacher competency in responding to these changes.

Source: Research 2024

AR can be used as a learning tool to help prepare the younger generation for an uncertain future. How we manage the use of AR can improve the quality of education in Indonesia, both now and in the future. Education plays a crucial role in improving the quality of human resources and creating an innovative and competitive generation in the era of Society 5.0. Incorporating AR into education is one way to achieve this goal. Thus, AR can help prepare the younger generation for an uncertain future.

The use of AR in learning can increase students' motivation and interest in learning, improve their understanding of learning concepts, increase real perception, and enable students to experiment, acquire practical skills, and develop future generations to become competent in technology based on knowledge (AlGerafi et al., 2023; Fauzziyah, 2019). Learning using AR in schools can have a significant impact on students' ability to understand learning concepts (Aprinaldi et al., 2019). This is because the text, graphics, videos, and audio displayed in the real-time environment of the students will provide a different experience for them (Belani & Parnami, 2020). In addition to the benefits provided, the world of education must pay attention to the impact of AR when it is implemented, such as the availability of hardware and connectivity in the educational environment, educational skills in mastering the technology, and the quality of the content of the AR (Fitriani, 2024; Akbar & Djakariah, 2023). Innovations in educational technology that have benefits in terms of broader and more flexible access to education, interactive and in-depth learning

experiences, and increased collaboration and communication must be supported by the development of digital skills and readiness to face various changes (Legi, 2023).

AR as a learning medium can help improve students' critical thinking skills and make the learning process more interactive and engaging. AR can help prepare the younger generation for an uncertain future. However, thorough preparation is also necessary, taking into account technological developments, teachers' skills in teaching with technology, and the quality of content produced through AR. Teachers also need to consider various studies that describe the development of AR use to make decisions about adopting AR technology in education (Avila-Garzon et al., 2021).

CONCLUSION

Education in the era of Society 5.0 focuses on integrating technology into the learning process. This technological innovation in education can prepare future generations to face the challenges and opportunities of this century, creating a more progressive and sustainable society. Augmented Reality (AR) is one of the most exciting technological innovations for educational applications. AR manipulates reality by displaying objects in three dimensions, thus creating the illusion that the user is viewing something in the real world. In its application, AR provides many benefits for both students and teachers in achieving learning objectives. AR can also help improve students' critical thinking skills and make the learning process more interactive and engaging. The application of AR in education in Indonesia has great potential to improve the quality of education. Therefore, efforts are needed to develop the application of AR in education in Indonesia.

AUTHOR'S NOTE

In this research, the author declares that there is no conflict of interest related to the publication of this article. The author's aim is to review and analyze the development and application of Augmented Reality in Education in the Society 5.0 Era, without the intention of judging or judging others. The author also confirms that the data and content of this article are free from plagiarism.

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