

LEARNING MATHEMATICS THROUGH THE APPLICATION OF AUGMENTED REALITY (AR) TECHNOLOGY MEDIA

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Abstract (English)

Augmented Reality (AR) has emerged as an important innovation in education, especially in mathematics learning. The purpose of writing this article is to determine the application of AR technology media in mathematics learning. The research method in this article is systematic literature, this research highlights the positive impact of AR on student engagement, conceptual understanding, and learning outcomes. AR enables interactive visualizations that help students overcome barriers in understanding mathematical concepts. The results of this research found that AR increases student interest and encourages a more interactive learning environment. Apart from that, AR-based learning media has high validity, practicality and effectiveness. AR is not only suitable for one level of education but can also be applied at various levels, from elementary to middle school. Positive responses from students reinforce that AR is a feasible and practical tool to use in mathematics learning. Thus, AR shows great potential to transform mathematics learning in the digital era, helping students better understand complex concepts and increasing their engagement in the learning process.

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Augmented Reality,
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INTRODUCTION

Learning media is a tool that bridges interactions between educators and students in the teaching and learning process, which functions to connect, convey information and channel messages to create effective and efficient learning. According to Atsani (2020), learning media is one of the most important aspects in the learning process, in fact the success of the learning process really depends on the media used.

Aixia Ying and Wijaya (2020) stated that world development cannot be separated from technology, including in the field of education which is facing new challenges in the form of the application of technology in teaching and learning activities in the classroom (Hernawati & Jailani, 2019). Technology is an effective and efficient tool that can be used to develop learning media (Wijaya Purnama & Tanuwijaya, 2020). Therefore, with the right touch of technology, learning media is expected to increase students' interest and learning abilities.

Technological developments have changed the world of education significantly, especially through the use of devices such as computers, the internet and mobile which modernize learning and teaching methods. However, the integration of this technology poses challenges in ensuring an effective learning process, including developing digital skills for educators and students as well as maintaining data security. 21st century education must focus on improving critical thinking skills, real-life applications of science, and skills in information and communication technology. One of the important innovations that has emerged is the use of Augmented Reality (AR) to prepare students to face future challenges. (Hidayat & Aslamah, 2020)

Augmented Reality (AR) was first introduced by Tom Caudell in 1990 and is a technology that combines real world elements with virtual elements through devices such as smartphones or smart glasses. AR allows users to view and interact with virtual objects that appear to blend into their physical environment, creating a blend of reality and imaginative elements. This technology combines aspects of Virtual Reality (VR) with real-world images, providing significant benefits, especially in the educational field. AR can enrich the learning

experience by providing interactive and visual content, which is especially useful in academic contexts such as mathematics, science, and engineering, which require a practical and experimental approach. (Luthfi et al., 2024).

The development of AR technology is expected to create a more immersive experience and greater benefits in various aspects of daily life, including responding to challenges in the world of education. One of the main challenges in mathematics education is low student involvement or interest. To overcome this, teachers can utilize AR-based learning media and apply more varied and interactive teaching methods. This approach can make mathematics learning more interesting, thereby increasing students' interest and involvement in the learning process (Putri et al., 2019).

One of the effective learning media to increase student engagement and interest in learning is augmented reality (AR). According to Azuma (in Arifin et al., 2020), AR is a technology that integrates the real world with virtual elements through the display of three-dimensional (3D) objects in the physical environment, making it look like part of the real world. AR also makes it possible to present illustrations that are difficult to present physically. In contrast to virtual reality which completely replaces reality, AR complements and enriches real experiences in real-time. (Rozi et al., 2021).

Sanjaya (in Rizal & Yermiandhoko), the main component in Augmented Reality (AR) is the 3D object that appears when the marker is scanned by the application or software, which makes students more interested because of the animation of the 3D object (Sungkono et al., 2022). AR has several advantages, such as effectiveness in use, flexibility in various forms of media, ease of operation, relatively low manufacturing costs, and higher interactivity compared to other media (Widyasari & Ismawati, 2020). Based on this, this research aims to examine the use of Augmented Reality in mathematics learning.

RESEARCH METHODS

This research uses the SLR (Systematic Literature Review) method, which involves the stages of identification, review, evaluation and interpretation of all relevant research. The SLR method is carried out by systematically reviewing and identifying articles, following established procedures at each stage (Triandini et al., 2019).

This research examines the Transformation of Mathematics Learning through Augmented Reality Media with a focus on Student Engagement and Conceptual Understanding. Using secondary data from journals, proceedings, books, and other relevant sources, the analysis was carried out in three stages: organizing relevant data, synthesizing study results to be comprehensive, and identifying important information for research findings. The research results are presented in the form of a discussion in this article.

DISCUSSION

The results of the analysis of articles discussing the use of AR in mathematics learning can be seen in Table 1.

No	Writer	Method	Results
1	Lutfi Siva Fauziah, Sugiman, Detaila Noriza Munahefi (2024)	Qualitative	The results showed that (1) AR increases student participation and interest in mathematics, (2) AR deepens understanding of mathematical concepts through visual experiences that overcome difficulties, and (3) there is a positive relationship between

			student engagement and concept understanding, with higher engagement associated with better understanding. This research contributes to the understanding of the transformation of mathematics learning through AR.
2	Sugeng Sungkono, Vepi Apiati and Satya Santika (2022)	Research & Development	The result of this research is an Augmented Reality-based learning media for pyramid material called GEO3DAR. This media is considered to have good quality content and objectives, while its instructional quality is considered very good.
3	Riski Meilindawati, Zainuri, Isti Hidayah (2023)	Qualitative	Research found that the use of augmented reality-based learning media is very well applied to students, helps mathematics learning, improves learning outcomes, and improves students' various mathematical abilities.
4	Jaka Sutresna, Fitri Yanti, Andin Eka Safitri (2020)	Research & Development	This development research shows that Augmented Reality-based mathematics learning applications make it easier for young children to learn mathematics and provide an interesting way for them to understand mathematical concepts.
5	Bellariksa Suliyono, Yuniar Ika Putri Pranyata, Timbul Yuwono (2022)	Research & Development	Trials of the effectiveness of Augmented Reality-based media showed that students' mastery scores reached 100% in both small and large group trials. This shows that the media developed is valid, practical and effective for learning three-dimensional material at SMK Negeri 11 Malang.
6	Leonardo Yang, Wilda Susanti, Alyauma Hajjah, Yulvia Nora Marlim and Gusrio Tendra (2021)	Multimedia Development Life Cycle (MDLC)	Testing of the mathematical learning model application for geometric shapes and plane shapes using AR technology shows that the application is suitable and functions well according to the black box test results. This

			application is an effective alternative for 2nd grade elementary school students to use smartphones in AR-based mathematics learning.
7	Khotimah, K., & Satiti, W.S. (2019)	Research and Development	This research found that Augmented Reality-based learning media on flat-sided geometric material is very valid and effective. The use of this media encourages positive responses from students and helps them achieve learning completion criteria.
8	Larasati, NI, & Widyasari, N. (2021)	Qualitative	This research found that AR learning media was able to improve students' mathematical understanding, although no significant differences were found in students' learning styles.
9	Saputri, S., & Sibarani, AJ (2020)	Research and Development	This research shows that learning media in the form of Android-based augmented reality markers is suitable for use in learning. This application functions well, can scan and display image objects even in low light conditions, and can reflect image objects as far as 50 cm
10	Widayanti & Dwi Nur'aini, (2020)	Descriptive statistics	This research found that Android-based learning media products developed using Augmented Reality have been validated by experts and are considered very practical. The learning outcomes of students who use this media are better than students who use conventional learning methods.

Augmented Reality (AR) is a technology that combines digital elements with the real world through devices such as smartphones, tablets or smart glasses. This technology allows users to view and interact with virtual objects that appear to be part of their surroundings. AR utilizes Information and Communications Technology (ICT) as well as devices with cameras to display virtual objects on top of real-world views, utilizing sensors and data processing. AR offers flexibility and creativity in its application, making it suitable for distance learning, both formal and informal.

Augmented Reality (AR) media integrates images, video, audio, and text in a real environment, providing a media experience that seems real for students. Dewi & Sahrina

(2021) stated that AR can attract and motivate students by making two-dimensional objects appear more real. Research from 10 articles shows that AR is highly effective in mathematics learning, offers an interactive and immersive learning experience, and supports meaningful learning with advanced technology.

The Effectiveness of Using AR in Learning has been carried out in various studies using Research & Development (R&D) methods, such as that carried out by Sugeng Sungkono et al. (2022), Bellariksa Suliyono et al. (2022), and Khotimah & Satiti (2019), confirmed that the AR-based learning media developed has a high level of validity, practicality and effectiveness. The trial results show that students who learn using AR-based media show better learning outcomes compared to students who use conventional learning methods.

Augmented Reality (AR) applications are effective at various levels of education, including elementary schools for material on spatial and flat shapes. The use of AR in mathematics increases student interest and motivation compared to traditional methods. AR is also practical in a variety of conditions, including less than optimal lighting, and helps overcome barriers to understanding concepts with clear visual representations.

CONCLUSION

Overall, this literature review shows that Augmented Reality (AR) has a positive impact on mathematics learning by increasing student engagement, concept understanding, and learning outcomes. AR makes learning more interesting and effective in addressing abstract concepts, as well as practical at various levels of education, making it a potential tool for the transformation of mathematics learning in the digital era.

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