

The Utilization of Virtual Reality Technology to Enhance Student Motivation in Mathematics Lessons: A Systematic Literature Review

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Abstract: The objective of this study is to conduct a systematic literature review on the utilization of virtual reality (VR) technology to enhance student motivation in mathematics lessons. Literature sources were retrieved from Google Scholar, DOAJ, and Scopus indexes, covering publications from 2014 to 2024. The research findings indicate that the utilization of virtual reality (VR) technology in mathematics education demonstrates significant potential in boosting student motivation by providing more engaging and interactive learning experiences. The integration of VR technology in mathematics education can create dynamic and effective learning environments, resulting in a positive impact on student engagement and interest in mathematics lessons. These findings underscore the importance of VR in enhancing the effectiveness of mathematics education and stimulating student interest in the subject matter.

Keywords: Virtual Reality, Mathematics Education, Student Motivation, Enhancement.

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A. INTRODUCTION

The significance of mathematics in the context of education is undeniable. A profound understanding of this subject plays a central role in determining individual success in various fields. Mathematics is not merely considered an academic discipline; it serves as a crucial foundation supporting problem-solving abilities, critical thinking, and analytical skills (Mella et al., 2022). In various fields such as science, technology, engineering, and economics, a robust knowledge of mathematical concepts like algebra, geometry, and statistics becomes a primary key to tackling complex challenges and pursuing innovation (Sutisna, 2019). Regardless of fields that may not directly relate to mathematics, such as arts and humanities, the ability to think logically and analyze information becomes a highly valuable aspect. Therefore, learning mathematics is not just about understanding formulas and theories but also about developing critical thinking skills and problem-solving abilities that will be beneficial throughout one's life.

Challenges faced by students in motivating themselves to learn mathematics include factors such as decreased interest, fear, and boredom that often arise during the learning process (Sahara et al., 2023). Decreased interest occurs when students feel less engaged or

perceive mathematics as irrelevant to their daily lives mereka (D. A. Putri et al., 2020). Fear can be a significant obstacle, especially for students who feel anxious or lack confidence in handling perceived difficult mathematical concepts. This fear is often triggered by perceptions of the difficulty of mathematical material or pressure to achieve a certain level of proficiency. Additionally, boredom can arise when mathematics learning is considered monotonous or lacks interest, especially if the teaching methods used are less diverse or do not consider individual learning styles (Uma et al., 2021). When students feel trapped in unchallenging routines, they tend to lose interest and motivation to learn. In some cases, the lack of relevance between mathematical content and everyday life can also trigger boredom. All these challenges can negatively impact students' motivation to learn mathematics, resulting in decreased academic performance and interest in the subject. Therefore, understanding and addressing these challenges is crucial to creating a supportive learning environment that motivates students to succeed in mathematics.

The development of technology, particularly virtual reality technology, has become a crucial element in modern education that provides solutions to challenges faced by students in motivating themselves to learn mathematics (Kalionga et al., 2023) (Amelia, 2023). In the realm of education, virtual reality has become an integral part that offers significant potential in creating engaging and captivating learning experiences (Sutanto, 2020). Through this technology, students can engage in realistic and interactive learning experiences that allow them to be directly involved in the mathematics learning process. For example, using virtual reality applications, students can visualize mathematical concepts more clearly, explore complex mathematical structures, or even participate in challenging simulations. Therefore, virtual reality technology not only brings innovative learning approaches but also helps overcome challenges such as boredom or lack of student engagement in mathematics learning. By leveraging the potential of this technology optimally, educators can create more interesting and motivating learning experiences, which, in turn, can enhance students' understanding and performance in mathematics.

The implementation of virtual reality technology in mathematics learning has yielded significant positive impacts on student motivation and engagement (Ridloka et al., 2023) (Cevikbas et al., 2023). Research has revealed that the use of virtual reality in the context of mathematics learning can increase students' interest and motivation, as well as improve their problem-solving abilities (Dewi et al., 2023). Furthermore, VR also has the potential to consolidate socio-emotional, cognitive/metacognitive, and pedagogical developments in students' understanding of mathematics (Kondratavičienė, 2023). The use of visual learning media, including VR, has also proven effective in strengthening students' interest and enthusiasm for mathematics learning (Nurhayati & Arif, 2023). Moreover, the integration of VR and artificial intelligence technology has been proven to provide adaptive responses to the individual learning needs of students, significantly enhancing their understanding of mathematical concepts. Overall, the application of VR in mathematics education demonstrates great potential in improving student motivation, engagement, and understanding of mathematical concepts.

The implementation of virtual reality technology in mathematics learning has provided several significant benefits for students. Firstly, VR enables engaging interactions between students and mathematical concepts within the VR environment, thus enhancing their understanding of the taught mathematical concepts (Ridloka et al., 2023). Secondly, VR can increase students' levels of engagement in the mathematics learning process by presenting a more interactive and enjoyable learning experience (Cevikbas et al., 2023). Additionally, the use of VR can create a sense of achievement and success for students, motivating them to continue learning mathematics with high enthusiasm (Betts et al., 2023). Furthermore, VR technology also has the potential to enhance students' spatial visualization abilities, a crucial aspect for academic achievement in STEM fields (Nurhayati & Arif, 2023). Overall, the use of VR technology in mathematics learning can significantly contribute to improving concept understanding, increasing student engagement, and fostering a sense of achievement that motivates them to excel in learning mathematics (A. Putri et al., 2023).

The implementation of virtual reality technology in mathematics learning does face some challenges and drawbacks. Technical disruptions, high implementation costs, initial efforts required, health issues, and a lack of familiarity with VR technology are some challenges that can hinder the successful implementation of VR in classrooms (Cevikbas et al., 2023). Additionally, failures in designing flexible schedules, difficulties in supervising student work, and inconsistent use of collaborative communication tools have been identified as constraints in developing virtual mathematics tutoring programs (Zydney & Hord, 2023). Nevertheless, it is undeniable that VR has the potential to enhance learning and cognitive development in the context of mathematics education (Betts et al., 2023). Studies have shown that VR-based training can improve participant performance and mental workload in spatial visualization tasks, a crucial aspect for academic achievement in STEM (Dini Rahmawati et al., 2022). Moreover, the use of VR-based mathematics learning media with an ethnomathematical approach has proven effective in improving student learning outcomes (Uteuliev & Madyarov, 2022). Therefore, despite facing challenges, the benefits and potential of using VR in mathematics learning have been proven and have positive impacts.

This research aims to explore and synchronize gaps in the literature regarding the implementation of virtual reality (VR) technology in mathematics learning, focusing on two main aspects. First, the research will further examine the effectiveness of VR in improving students' understanding of mathematical concepts by comparing learning outcomes between those who use VR and those who do not. Second, the research will pay attention to efforts to overcome technical and logistical challenges in implementing VR in classrooms, including the development of training strategies for teachers and research to minimize implementation costs. Using a systematic literature review approach, this research aims to investigate how the implementation of VR in mathematics learning can enhance student motivation.

B. METHOD

This research aims to investigate the use of virtual reality technology as a means to enhance students' motivation in learning mathematics. The focus of the study is to comprehend the impact of virtual reality technology on student motivation in the context of mathematics education and to provide a profound understanding of its effectiveness as a

supportive learning tool. Literature search was conducted through three primary data sources, namely Scopus, DOAJ, and Google Scholar, spanning the period from 2014 to 2024. Keywords used include terms such as virtual reality, mathematics education, student motivation, and improvement.

Inclusion criteria for articles included in this research encompass studies or research that discuss the utilization of virtual reality technology in mathematics education, as well as studies specifically examining its impact on student motivation. Meanwhile, exclusion criteria involve articles that are irrelevant to the topic or do not meet the established inclusion criteria. The article selection process involved several steps, including duplicate removal, title and abstract screening, full-text reading, and extraction of relevant data from the selected articles. Extracted information includes author details, publication year, research methodology, main findings, and conclusions. With this approach, it is anticipated that this research will provide a profound understanding of the utilization of virtual reality technology in enhancing student motivation in mathematics education.

C. RESULTS AND DISCUSSION

1. The Use of Virtual Reality Technology in Mathematics Education Can Enhance Student Motivation

The utilization of virtual reality (VR) technology in mathematics education has been proven effective in increasing student motivation and engagement (Ridloka et al., 2023) (Muthmainnah et al., 2023) (Beluce & De Oliveira, 2015). Previous studies indicate that VR can enhance students' interest and motivation in learning mathematics, while also improving their problem-solving abilities (Cohen-Nissan & Kohen, 2023). Metaverse technology, including VR, has the potential to enhance student engagement and encourage active participation in the learning process, subsequently improving academic performance (Brown et al., 2023). Additionally, the use of immersive technologies like VR has been shown to increase undergraduate students' motivation to learn and deepen their understanding of academic materials. The use of VR in distance education has also proven to have a positive impact on student motivation, engagement, and satisfaction compared to traditional online methods. Overall, research results indicate that the use of VR technology in mathematics education can positively contribute to student motivation and engagement.

Several studies have found that the use of virtual reality technology in mathematics education can significantly enhance student motivation. Cahyono & Suharto (2022) developed a framework for a virtual classroom using three-dimensional hologram (3DH) technology, which was found to increase student motivation. This finding is consistent with the research by Wajdih et al. (2020), reporting that Realistic Mathematics Education (RME) can enhance student motivation and learning outcomes. Elvianasti et al. (2022) further support this, demonstrating a significant correlation between motivation and science students' learning outcomes. Jumaini et al. (2021) also found that integrated learning methods, often incorporating virtual reality technology, can significantly improve students' understanding of concepts and learning outcomes. These studies collectively suggest that the use of virtual reality technology in mathematics education can indeed enhance student motivation.

The use of VR technology in mathematics education provides a more engaging and realistic learning experience for students. By presenting mathematical content in a virtual environment with visual and interactive elements, students are more motivated to participate in learning. Furthermore, the presence of VR in education can boost students' confidence in understanding and solving mathematical problems, as they can face situations similar to the real world directly. The cited research results consistently highlight the positive impact of using VR technology in increasing student motivation in mathematics education. However, it is essential to note that there is variation in the methods of using VR technology and differences in research contexts that can affect its effectiveness. Additionally, despite the research indicating increased student motivation, it is crucial to consider other factors that can also influence student learning outcomes, such as teachers' instructional abilities and curriculum design.

2. Factors Influencing the Effectiveness of Virtual Reality Technology in Enhancing Student Motivation in Mathematics Education

The implementation of Virtual Reality (VR) technology has proven to enhance student motivation in the context of mathematics education. Several factors influencing the success of VR in achieving this include the design of Virtual Learning Environments (VLE) (Cohen-Nissan & Kohen, 2023). Within VLE, structured activities, learning materials, instructional guidance, and collaborative learning have been shown to support students' competence and motivation in mathematical modeling tasks (Beluce & De Oliveira, 2015). The application of advanced immersive technology, such as 3D animations and virtual reality glasses, has also been proven to stimulate students' motivation to learn (Ferdinand et al., 2023). Providing relevant information to students about the benefits of using VR before initiating virtual learning can enhance their perception of VR's value and result in improved learning outcomes (Dini Rahmawati et al., 2022). The use of VR-based mathematics learning media with an ethnomathematical approach has also proven effective in enhancing students' learning achievements and understanding of mathematical concepts (Ridloka et al., 2023). Overall, the use of VR in mathematics education can increase students' interest, motivation, and problem-solving abilities.

Various factors influence the effectiveness of virtual reality technology in enhancing student motivation in mathematics. These factors include students' oral and written communication skills Suryawati et al. (2023), prior knowledge, appreciation for mathematics, and mathematical logical intelligence Irawan et al. (2016), as well as experiences, abilities, time, attitudes, and motivation (Herizal, 2020). Additionally, internal factors such as physical and psychological aspects, fatigue, and external factors such as family, school, and community play a role Iskandar et al. (2016). Together, these factors shape the potential of virtual reality technology to enhance student motivation in mathematics.

From these research findings, it can be concluded that the effectiveness of VR technology in enhancing student motivation in mathematics is influenced by diverse factors. Engaging virtual learning environment design, the use of immersive technology, and appropriate teaching approaches such as ethnomathematical approaches all contribute to creating an engaging and effective learning experience. Furthermore, providing relevant information to

students about the benefits of using VR has a significant impact on students' perceptions and learning achievements. Research results consistently highlight the roles of these factors in improving the effectiveness of VR technology in mathematics education. However, it is important to note that there is a need for further research to deepen understanding of these factors and how they interact. Additionally, there are other aspects that may affect the effectiveness of VR in mathematics education that need consideration, such as contextual factors and student characteristics.

3. Previous Research Findings on the Implementation of Virtual Reality Technology in Mathematics Education Provide Insights into the Potential and Challenges in Enhancing Student Motivation

Previous research on the use of virtual reality (VR) technology in mathematics education offers insights into the potential and challenges in enhancing student motivation. These studies demonstrate that the integration of VR in mathematics education can increase children's interest and motivation in the learning process, as well as enhance their problem-solving abilities (Ridloka et al., 2023). Furthermore, VR has the potential to strengthen socio-emotional, cognitive/metacognitive, and pedagogical development in students during mathematics learning (Cevikbas et al., 2023). Findings also indicate that the use of VR can improve student motivation, engagement, and satisfaction compared to conventional online methods (Brown et al., 2023). The use of VR has also been proven to enhance students' self-perception of their abilities and interest in mathematical modeling tasks (Cohen-Nissan & Kohen, 2023). Additionally, training utilizing VR with spatial visualization tasks has demonstrated improvements in learning and performance in STEM fields (Betts et al., 2023). However, challenges such as technological disruptions, costs, initial efforts, health issues, and a lack of understanding of VR still need to be addressed for successful VR implementation in classrooms.

Previous research has shown that the application of virtual reality technology in mathematics education has the potential to enhance student motivation and learning outcomes. Hasan (2023) found that realistic mathematics learning can increase student participation and performance. Similarly, AIP (2021) reported that realistic mathematics learning can improve students' cognitive learning outcomes and attitudes. However, Putra (2018) emphasized the need to connect mathematical content with real-world problems to enhance learning outcomes. Nabilah et al. (2021) highlighted challenges such as anxiety and a lack of environmental support in virtual learning, suggesting the need for a comfortable and supportive virtual learning environment.

These research findings indicate that the implementation of VR in mathematics education holds significant potential for improving student motivation. This is evident from increased student interest and motivation in the learning process, as well as an enhanced self-perception of students' abilities and interest in mathematical modeling tasks. Furthermore, VR has the potential to strengthen various aspects of student development, including socio-emotional, cognitive/metacognitive, and pedagogical dimensions. While research highlights the positive potential of using VR to enhance student motivation in mathematics education, several

challenges need to be addressed. These challenges include technological disruptions, implementation costs, required initial efforts, health concerns, and a lack of understanding about VR. Additionally, some studies also highlight challenges in the form of anxiety and a lack of environmental support in virtual learning.

D. CONCLUSION

Based on the synthesis and re-evaluation of the conducted research, several conclusions can be drawn. The utilization of Virtual Reality (VR) technology in mathematics education demonstrates significant potential in enhancing student motivation by providing a more engaging and interactive learning experience. The integration of VR technology in mathematics education can create a dynamic and effective learning environment. However, there are several challenges that need to be addressed, such as technological disruptions, implementation costs, and a lack of understanding about VR. To maximize the benefits of using VR technology in mathematics education, further research is required. This research should consider specific aspects such as the impact of contextual factors and appropriate implementation strategies.

A gap in current research lies in the lack of in-depth understanding of how contextual factors, such as student characteristics and the learning environment, influence the effectiveness of using VR technology to enhance student motivation in mathematics education. Additionally, there is a need for more comprehensive research on effective implementation strategies to ensure optimal integration of VR technology into the mathematics curriculum. Therefore, a pressing research topic for the future is "The Influence of Contextual Factors and Implementation Strategies on the Effectiveness of Using Virtual Reality Technology to Enhance Student Motivation in Mathematics Education." It is hoped that this research will provide a deeper understanding of how VR technology can be effectively utilized to enhance student motivation in mathematics education, taking into account various contextual factors and appropriate implementation strategies.

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