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Teachers' Integration of Immersive Virtual Reality in Enhancing High school students' Mathematics Competence in an Online Learning Environment: A Narrative Review

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Abstract. This review paper aims at narrating the design and integration of immersive virtual reality (IVR) in teachers' instruction in enhancing high school students' mathematics competence in an online learning environment. The study aims to answer three research questions: the current state of IVR in Mathematics Education, the potential benefits of using IVR, and the limitations of using IVR. The study will utilize a narrative review and evaluate empirical studies on the effectiveness of IVR in enhancing high school students' mathematics competencies. A search would be conducted in electronic databases such as APA PsycINFO, Science Direct, Web of Science, Eric, and ProQuest Central for relevant studies published from 2010 to 2023. The expected results would provide insights into the potential of IVR in improving mathematics competence in an online environment and highlight key benefits and challenges. This presentation would also provide recommendations for educators and policymakers to integrate IVR into online mathematics education.

Keywords: Immersive Virtual Reality, High School, Mathematics Competence, Online Learning.

1 Introduction

Incorporating Immersive virtual reality (IVR) technologies into education, teaching, and training across different application domains is currently a growing trend [8]. The advancements in immersive technologies, particularly in terms of visualization and interaction, have made IVR an increasingly appealing option.

Immersive Virtual Reality (IVR) is a type of virtual reality that provides users with a highly interactive and engaging experience by simulating a real-life environment. In contrast to other types of virtual reality, IVR creates a sense of presence that is like real-life experiences [5]. According to a study, IVR technology is particularly useful in creating immersive educational experiences, such as in the field of mathematics education, where it can be used to provide students with hands-on learning opportunities and help them develop important skills and competencies [8]. As such, IVR has gained increasing attention as a promising tool for enhancing learning outcomes and improving student engagement in a variety of educational settings. Hence, there is a need for reviews of the effectiveness of IVR to gain insight into its potential for teaching and learning mathematics concepts.

In recent years, the use of Immersive virtual reality (IVR) technology has been increasingly explored as an innovative tool for enhancing learning experiences in various fields, including education. Specifically, the integration of IVR by teachers has shown great potential for improving mathematics competence in online learning environments [10]. With the global shift towards online learning due to the COVID-19 pandemic, this topic has become even more relevant and urgent.

The use of IVR in math education is based on several theoretical frameworks, including constructivism, and situated learning. These theoretical frameworks suggest that learners can construct knowledge through their experiences, interactions with the environment, and engagement with relevant and meaningful content [4]. IVR provides learners with immersive and interactive environments where the learners can explore mathematics concepts and ideas by manipulating virtual objects and engaging in simulations.

Several studies have explored the effectiveness of IVR in enhancing mathematics competence among high school students in online learning environments [1]. For example, a study investigated the use of IVR-based geometry instruction in an online learning environment and found that the use of IVR led to significant improvements in students' spatial visualization ability and geometry achievement [6].

Research has shown that incorporating IVR technology in mathematics education can have numerous benefits for students. For instance, IVR has improved engagement, motivation, and understanding of mathematics concepts [1]. It has also been shown to enhance students' knowledge retention, problem-solving skills, and spatial visualization abilities, which are important components of mathematical competencies [12].

Additionally, by integrating IVR into teaching, high school teachers can provide students with a more interactive and collaborative learning experience, aligning with the constructivist education approach [4]. Also, Liu et al. [7] found that students who used an IVR-based geometry learning tool showed greater improvements in geometry knowledge and spatial ability compared to those who used traditional 2D learning tools. Interactive feedback and hands-on exercises with IVR have also been shown to improve students understanding and knowledge of fractions [3], as well as their performance and attitudes toward studying mathematics [9].

Despite growing evidence of the effectiveness of IVR in education, there has been limited and insufficient synthesized research in mathematics education with online learning settings. A study corroborated the need for more research studying the situated design of virtual reality in mathematics education, particularly in an online environment [12].

This review paper aims to explore the design and integration of IVR in enhancing mathematics competence in an online learning environment. In this paper, the current state of IVR in mathematics education will be illustrated, as well as studies that have explored the effectiveness of IVR and a critical analysis of the findings will also be provided.

Specifically, the study seeks to answer the following questions:

1. What is the current state of the field regarding the use of IVR technology by teachers in enhancing mathematics competence in online learning environments?
2. What are the potential benefits of using IVR technology by teachers in mathematics education, particularly in online learning environments?
3. What are the limitations of using IVR technology by teachers in mathematics education, particularly in online learning environments?

2 Method

The research study will utilize a narrative review approach. This will involve synthesizing existing evidence related to the use of Interactive Virtual Reality (IVR) in enhancing high school students' mathematical competencies in online learning environments. To conduct this review, a comprehensive search will be carried out in electronic databases such as APA PsycINFO, Science Direct, Web of Science, Eric, and ProQuest Central. The search will be restricted to studies published between 2010 and 2023.

The review will identify and evaluate empirical studies that have utilized IVR to enhance high school students' mathematical competencies, specifically in problem-solving, critical thinking, and logical reasoning. Additionally, the review will explore the advantages and disadvantages of using IVR in mathematics education and the potential of IVR in the future of mathematics education. Fig.1 below depicts the phases and steps of a narrative literature review that will be followed in this review from planning, implementation, and reporting.

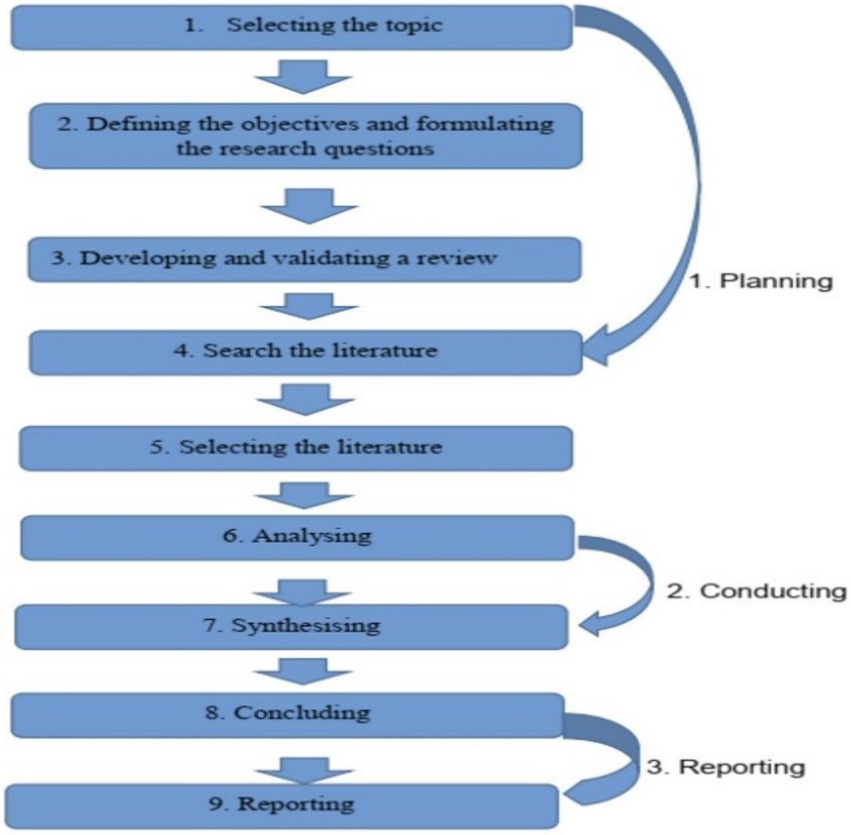

Fig. 1. A Search strategy adapted from Juntunen and Lehenkari (2021).

2.1 **Searching Process**

The set of keywords comprising "Immersive Virtual Reality," "virtual reality," "augmented reality, “immersive", "Mathematics Education," "Math," "Math education," “high school,” “secondary school,” "e-learning," "online learning," and "distance learning" was used to search for academic literature and research studies that explored the intersection of virtual reality technologies, mathematics education, high school, and online learning. These keywords were intended to identify resources that examine how virtual reality could be used to teach mathematics effectively through e-learning or online learning setting. The search was conducted using electronic databases including APA PsycINFO, Science Direct, Web of Science, Eric, and ProQuest Central, and the results of the initial search are summarized in Table 1.

Despite the rigorous selection criteria, certain limitations and challenges arose during the search process, such as the need to fine-tune and filter the search terms and results to ensure their relevance and accuracy, and the relatively limited number of sources retrieved in some databases. Moving forward, the research will entail a thorough analysis of the retrieved sources to identify key themes and trends associated with the use of virtual reality in mathematics education.

The next steps in this research involve analyzing the retrieved sources to identify common themes and trends related to the use of IVR technology by teachers for enhancing mathematics competence in online learning environments. The findings will then be synthesized to develop a comprehensive understanding of the current state of the field and to identify any gaps or opportunities for further research in this area. The ultimate objective is to establish a framework or model that effectively utilizes IVR technology for the teaching of mathematics in e-learning or online learning environments.

Table 1. Result of the initial search of the databases.

Database	Keyword	Result
PsycINFO	(mathematics or math or "math education" or "mathematics education") AND ("virtual reality" or vr or" augmented reality" or immersive) AND ("high school" or "secondary school") AND ("online learning" or "e-learning or distance learning")	283
Science Direct	(mathematics or math or "math education" or "mathematics education") AND ("virtual reality" or vr or" augmented reality" or immersive) AND ("high school" or "secondary school") AND ("online learning" or "e-learning or distance learning")	3
Web of Science	(mathematics or math or "math education" or "mathematics education") AND ("virtual reality" or vr or" augmented reality" or immersive) AND ("high school" or "secondary school") AND ("online learning" or "e-learning or distance learning")	16
ERIC	(mathematics or math or "math education" or "mathematics education") AND ("virtual reality" or vr or" augmented reality" or immersive) AND ("high school" or "secondary school") AND ("online learning" or "e-learning or distance learning")	56
ProQuest	(mathematics or math or "math education" or "mathematics education") AND ("virtual reality" or vr or" augmented reality" or immersive) AND ("high school" or "secondary school") AND ("online learning" or "e-learning or distance learning")	304
Total		662

2.2 **Inclusion and Exclusion Criteria for Data Collection**

Based on the inclusion criteria, the research will only consider empirical studies that investigate the impact of Immersive Virtual Reality on high school students' mathematics competence, and studies that demonstrate the use of IVR in an online environment. While the following exclusion criteria will be used for the data collection: Studies not written in English, studies unrelated to the research questions, duplicates of the same study results, studies that implement literature reviews, and studies not published between 2013 and July 2023.

2.3 **Data Extraction and Analysis**

The data extraction process will involve using a template in Excel to guide the retrieval of relevant data from each article that meets the inclusion criteria. The extraction form will include fields for key study characteristics such as study design, population characteristics, intervention details, outcomes, and results. Data will be extracted by two independent reviewers, and any discrepancies will be resolved through discussion and consensus. Once data extraction is complete, statistical analysis will be conducted to synthesize the results from the included studies and help to provide a comprehensive understanding of the impact of Immersive Virtual Reality (IVR) on high school students' Mathematics competence in an online environment.

3 **Expected Result**

The study will synthesize and summarize key findings from the selected literature to answer research questions and provide insights into the potential of IVR in improving mathematics competence in an online environment. The presentation of results will highlight the advantages and disadvantages of IVR in mathematics education and provide suggestions for the future of IVR in mathematics education. Recommendations for educators and policymakers to integrate IVR into online mathematics education would also be provided.

4 Conclusion

Integrating IVR in mathematics education has the potential to enhance learning and engagement by providing an interactive learning experience, and deepening understanding of mathematical concepts. We hope to provide insights into the potential of IVR in mathematics education, which can help educators and policymakers make informed decisions about the integration of IVR into online mathematics education.

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