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Enhancing Mathematics Education: The Impact of Virtual Reality on Pre-Service Teachers' Perceptions and Learning Outcomes

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Abstract

This study investigates the impact of virtual reality (VR) on mathematics education, focusing on pre-service teachers' perceptions and learning outcomes at Qatar University. Employing a mixed-methods approach, the research explores VR's potential to enhance comprehension and engagement in mathematics instruction. A cohort of 60 pre-service teachers participated in the study, which utilized both quantitative surveys and qualitative interviews. Results indicate favourable attitudes towards VR integration in mathematics education, with participants emphasizing its efficacy in visualizing complex concepts and increasing student engagement. However, challenges such as technological limitations, financial considerations, and integration into existing curricula were identified. The study reveals significant correlations between teachers' technological proficiency and their attitudes towards VR utilization, particularly in areas of performance, communication, and learning environment. These findings contribute to the expanding body of research on educational technology and provide valuable insights for curriculum development and teacher training programs aiming to incorporate VR in mathematics education.

Introduction

The rapid integration of Information and Communication Technologies (ICT) in education reshapes how subjects are taught and learned. In mathematics education, where visualization and interaction significantly enhance learning, Virtual Reality (VR) presents novel opportunities. This study explores VR's potential to improve understanding and engagement among pre-service mathematics teachers at Qatar University, aiming to fill the gap in immersive educational technology usage within this discipline. In an era defined by rapid advancements in information and communication technologies (ICT), the pervasive reach and accessibility of digital connectivity have reshaped the societal landscape into a closely-knit 'global village.' This profound transformation has been particularly impactful in the realm of education, where the integration of ICT has become not merely advantageous but essential. The capability to access a vast array of information from across the globe instantaneously has revolutionized the educational paradigm, shifting it towards a more inclusive, diverse, and resource-rich environment.

This global digital integration has underscored the critical role of ICT in enhancing the educational experience,

providing students with unprecedented access to information and computational resources that facilitate complex problem-solving and analytical tasks. Educational settings have increasingly embraced various digital tools, making it feasible for students to perform intricate calculations and engage with complex data sets with precision and without bias. These capabilities, as highlighted by Atteh et al. (2020), empower students to pursue a more self-directed and independent learning journey, one that is tailored to their individual pace and learning style.

Moreover, the necessity for educators to adapt to these technological advancements is increasingly recognized within the academic community. Educators are required not only to adopt new technologies but also to develop pedagogical strategies that effectively integrate these tools into the teaching process. Bingimlas (2009) emphasizes that modern-day educational technologies are crucial for teachers to enhance their teaching methods and engage with students in innovative ways. Similarly, Chatila et al. (2019) argues that technology is among the most effective solutions for addressing the diverse needs of different educational settings, advocating for a comprehensive integration of digital tools to enrich the learning and teaching process.

Despite the widespread adoption of general ICT tools in education, there remains a conspicuous gap in the utilization of more immersive and interactive technologies, such as Virtual Reality (VR), particularly in the domain of mathematics education. While VR technology has begun to make inroads in fields such as science and engineering education, its potential in mathematics—a subject that fundamentally benefits from visual and experiential learning—has not been fully explored. This gap is particularly noteworthy given VR's capability to simulate complex mathematical environments and visualize abstract concepts in ways that traditional educational tools cannot.

The current research seeks to bridge this gap by conducting a systematic investigation into the effectiveness of VR in enhancing the teaching and learning of mathematics at Qatar University. The study aims to evaluate how VR can transcend traditional pedagogical methodologies to offer a more immersive and engaging learning experience. It will explore VR's potential to enhance students' understanding of mathematical concepts through interactive simulations that provide a tangible sense of abstract theories and problems. By focusing on this underexplored area, the study will contribute significant new insights to the field of educational technology, offering empirical data on the impacts of VR on pre-service teacher engagement, comprehension, and academic performance in mathematics. This investigation is poised to inform future educational strategies and curriculum development, highlighting the practical implications of integrating cutting-edge technology like VR into traditional educational settings to foster a richer, more effective learning environment.

Theoretical Framework

Our theoretical foundation is grounded in Constructivist Learning Theory, which posits that knowledge is actively constructed through experience. VR's immersive environments provide a dynamic platform for active learning, making it an ideal tool for exploring complex mathematical concepts. We discuss how VR aligns with constructivist principles, facilitating deeper engagement and understanding among learners.

Introduction to Virtual Reality in Education

As we navigate through the digital revolution, Virtual Reality (VR) has surfaced as a transformative force within the educational sector. This technology, characterized by its capacity to simulate intricate, immersive environments, has established itself as a strategic enhancement to traditional educational methodologies, promising to advance the educational system significantly. Research by Mohamed et al. (2015) highlights VR's role not merely as a technological advancement but as a credible, efficient solution to contemporary educational challenges, leveraging state-of-the-art technology to elevate learning experiences.

Definitions and Educational Applications of VR

Virtual Reality is defined as a three-dimensional electronic learning environment that facilitates both synchronous and asynchronous interactions between educators and learners. This environment enhances the efficiency of discussions and the delivery of content, creating a classroom-like experience where educational materials are dynamically presented and interacted with. As Burov & Pinchuk (2023) articulate, this interaction is not passive but an active, engaging process. Expanding on this, Melinda & Widjaja (2022) describe VR as a versatile platform where educators can meticulously structure lessons, establish clear objectives, and interact with students via multimedia resources, thereby streamlining the access to and processing of educational content. Furthermore, Ajlouni et al. (2025) underscores the pivotal role of VR in reaching educational benchmarks by augmenting the digital competencies of educational stakeholders.

VR's Contributions to Educational Goals

The contributions of VR and educational software to achieving educational objectives are profound, as highlighted by Chaaban et al. (2024). These technologies not only supply high-quality educational content but also create optimal learning environments that utilize educational materials effectively, making the learning process both accurate and engaging. Al Saud (2019) and Al-Omari (2019) further note that VR not only elevates educational quality but also fosters the development of essential interpersonal skills such as empathy, cooperation, and social interaction—skills that are vital for future societal engagements.

From a theoretical viewpoint, the integration of VR in education can be extensively analyzed through the Constructivist Learning Theory. This theory advocates that effective learning occurs through active engagement where learners construct their own understanding from real-world interactions. VR's immersive capabilities render it an ideal tool for constructivist learning, especially in mathematics education where abstract concepts can pose significant challenges. VR allows students to visualize and manipulate mathematical elements in three-dimensional space, thus significantly enhancing the comprehension and retention of complex concepts.

Simonetti et al. (2020) explore how VR facilitates the exploration of geometric shapes and spatial relationships, rendering abstract mathematical theories more comprehensible and engaging. Additionally, VR environments can simulate real-world applications of mathematics, bridging theoretical knowledge with practical application in

various fields such as engineering, design, and the sciences. This not only boosts motivation but also contextualizes mathematical learning to real-life scenarios.

Challenges and Limitations

Despite its numerous advantages, the implementation of VR in education is not without challenges. The accessibility and affordability of VR technology present significant barriers, particularly for underprivileged populations. The requisite hardware and software for VR are costly, and there are additional concerns related to health and safety, such as motion sickness and eye strain. Rahmawati, Buchori, & Ghoffar (2022) stress that the effectiveness of VR content and its alignment with educational goals must be meticulously managed to cater to the diverse needs and learning styles of students.

Despite these hurdles, VR holds tremendous promise for transforming mathematics education through engaging, interactive, and inclusive learning experiences. It necessitates a collaborative approach among educators, administrators, and policymakers to meticulously plan, coordinate, and assess the integration of VR into curricula, ensuring it serves to enhance rather than detract from educational objectives. Continued research and development into VR applications, like Mathland and CalcFlow, which facilitate experiential learning and problem-solving in virtual settings, are crucial for realizing the full potential of VR in education.

In conclusion, virtual reality stands at the vanguard of educational technology, poised to fundamentally alter the teaching and learning of mathematics. By aligning VR innovations with educational theories and addressing its implementation challenges, VR can significantly contribute to a richer, more effective educational landscape. Through its support for constructivist approaches—ranging from experiential learning to social interaction—VR not only conveys knowledge but also transforms the very process of learning mathematics, making it a dynamic, interactive, and learner-centered experience. This theoretical alignment is essential for justifying the integration of VR in educational settings, ensuring that its deployment is both pedagogically sound and conducive to enhancing learning outcomes.

Literature Review

Several variables of this study, such as the importance of virtual classrooms in general and their usage in teaching mathematics in particular, have been discussed in the previous literature. Al-Aqali (2018) conducted a descriptive study to identify the obstacles to employing virtual reality in teaching mathematics from the point of view of mathematics teachers in Jeddah, Saudi Arabia. A questionnaire was distributed to a sample of 93 female mathematics teachers in the city of Jeddah. The results of the study found that the general arithmetic mean of the obstacles to using virtual reality in teaching mathematics from the point of view of the subject teachers was a degree of (strongly agree). There were no statistically significant differences between the averages of the responses of the research sample about the obstacles to using virtual reality in teaching mathematics that are attributed to the educational stage and the years of experience variables. Accordingly, the study recommended the necessity of providing devices and equipment with special specifications for using virtual reality in teaching

mathematics.

A seminal contribution has been made by Abdul-Hakim (2018), who conducted a study at Najran University to explore the faculty members' attitudes towards using virtual classrooms in teaching mathematics in the preparatory stages. Ten faculty members from the Basic Sciences Department were subjected to a set of research tools that included measuring their attitudes towards using virtual classrooms in teaching mathematics, an observation card to measure the implementation and evaluation of mathematics teaching, and an interview card to measure planning skills. The study was conducted in the second semester of 2017–2018. The results showed that the faculty members practice planning skills to a high degree for using virtual classrooms, practice implementation skills to a moderate degree, and practice evaluation skills to a low degree. The results indicated that there are no statistically significant differences in attitudes towards using virtual classrooms that are linked to experience or academic qualification variables. The study recommended the necessity of using virtual reality technology as a tool for teaching and learning mathematics because of its extra learning benefits in a wide range of mathematical fields.

Another study conducted by Al-Omari (2019) aimed to demonstrate the effectiveness of synchronous virtual classes in developing the professional performance of middle school mathematics teachers. The study relied on a quasi-experimental approach and consisted of a sample of 30 mathematics teachers in girls' schools in the middle stage in Al-Qunfudhah Governorate. The study tools applied to the sample included a list of professional performance skills for middle school mathematics teachers, a test of the cognitive aspect of professional performance skills, and an observation card of professional performance. The study was applied in the second semester of the academic year 1438–1439 AH. The results showed there were statistically significant differences in the cognitive test related to the aspect of professional performance skills. The study recommended the need to train mathematics teachers to use synchronous virtual classrooms.

Furthermore, a study by Demitriadou, Stavroulia & Lanitis (2020) aimed at using virtual reality and augmented reality technologies in teaching mathematics. Naccache et.al (2023) followed the experimental approach, where 30 fourth, fifth, and sixth grade students were divided into three groups that included a control group and two experimental groups. The two groups (the first and second experimental ones) used applications dedicated to virtual reality and augmented reality to learn about geometric solids, while the students of the control group used traditional printed materials as part of the learning process. The results indicated that applying new technologies in teaching virtual and augmented reality improves students' interaction and increases their interest in teaching mathematics, which contributes to increasing learning efficiency and a better understanding of mathematical concepts when compared to traditional teaching methods. The results also showed that no significant differences were found between virtual reality and augmented reality technologies regarding the efficiency of the methods that contribute to learning mathematics. This suggests that both virtual reality and augmented reality offer similar potential for mathematics activities.

Su, Cheng and Lai (2022) conducted a study on using virtual reality technologies to teach mathematical geometry concepts. The study tools included three basic materials for learning mathematical geometry: the volume of a

triangular pyramid, the volume of a cone, and the centres of gravity of a triangle and a circular sector. In the experimental activity, the teacher uses virtual reality teaching aids to guide students to learn mathematical engineering concepts in a fun way so that they can achieve the effectiveness of virtual learning. Accordingly, the study concluded with some generalizations stating that using a mathematical geometry system for virtual reality can improve students' motivation. The results also indicated that the experimental group achieved better learning outcomes after completing the learning tasks for three engineering units; hence, virtual reality is effective in developing students' academic achievement, and there are positive trends towards using virtual reality in teaching mathematics.

Aiming at finding out the impact of virtual reality technologies on the academic achievement of fourth-grade students in mathematics, Akman and Çakır (2023) relied on a quasi-experimental approach. A sample of 64 students was divided into two groups: a control and an experimental group, with 32 students in each group. They subjected the experimental group to an educational virtual reality game called "Keşfet Kurtul," which uses simple and gradual arithmetic operations to solve complex problems, while leaving the control group to teach in the traditional way. The results showed the effectiveness of virtual reality techniques in increasing academic achievement and maintaining the level of students' participation in mathematics classes. It was noted that Keşfet Kurtul was more effective than the traditional method used in school with regard to the sub-social dimension of student participation because it allows teachers and students to work together. The ability to easily connect students and train them in the same virtual classroom is one of the main benefits that helped increase the use of virtual learning. The results also indicated that this game helped students improve their mathematical skills while enjoying their lessons. The study stressed the importance of integrating images, static and animated or three-dimensional drawings and video clips that are suitable for the individual needs of learners.

To determine biology teachers' attitudes towards using virtual reality, Muslim (2022) found highly positive teachers' attitudes towards using virtual reality. There was also no effect of other variables such as academic qualification, years of experience, and attendance at workshops and training courses on the level of attitudes towards using virtual reality in teaching because there were no statistically significant differences in the responses of the sample that could be attributed to any of the aforementioned variables. Similarly, Kabir and Abdel Moneim (2017) found high positive attitudes among teachers towards using virtual laboratory technology in teaching at the secondary stage in Gedaref State, Sudan. They found no statistically significant differences between males and females in attitudes, and there was no effect of the specialization variable on the teachers' attitudes.

A key study by Al-Amari and Al-Kasi (2023) about teachers' perceptions of using virtual reality in its various types and styles investigated the use of virtual laboratories in the teaching of practical experiments in chemistry and physics in the Qunfudhah region in the Kingdom of Saudi Arabia. The study concluded that chemistry and physics teachers agreed on the effectiveness of virtual laboratories in assisting them in teaching, planning, implementing, and ultimately evaluating practical experiments. Therefore, these views could reflect the attitudes of these teachers towards the effectiveness of virtual laboratories in teaching practical experiments in chemistry and physics.

Methodology

The study aims to evaluate the effect of learning environments that are supported by VR on the success and motivation of students studying mathematics. The VR is used in teaching the types of triangles to secondary school students by measuring their inclinations before and after the application. This is monitored by a scale that measures three axes related to learning mathematics through technology: confidence in mathematics, confidence in technology, and attitude towards learning mathematics through VR.

Teachers normally prefer to use technology in their teaching practices due to their personal perceptions that technology is useful in reinforcing curriculum and educational practices. This is evidenced by a study conducted in Turkey by Can and Cagiltay (2006), who investigated the perceptions of a group of prospective computer teachers and their future plans. The results revealed that the participants showed positive perceptions towards using computers in education, mainly computer games with educational features. Even though some participants raised some doubts about classroom management and the efficiency of teaching with the new computer games currently available on the market.

Research Questions

The study sought to explore mathematics teachers' attitudes and perceived ICT skills in teaching and learning mathematics in some selected preparatory and secondary schools in Qatar. Hence, this research aims at examining the attitudes of preparatory and secondary school teachers about the use of information and communication technology especially virtual reality applications in teaching mathematics. The research also focuses on preparatory and secondary school mathematics teachers' skills in using and enhancing information and communication technology. Accordingly, this study addresses the following questions:

1. What are the attitudes of mathematics teachers in the public preparatory and secondary schools in Qatar in terms of their confidence about teaching mathematics and the use of technology in teaching?
2. What are the attitudes of mathematics teachers in the public preparatory and secondary schools in Qatar towards technology-assisted mathematics teaching virtual reality applications?
3. Are there statistically significant differences in attitudes among the sample that are linked to the teachers' nationality?
4. Are there statistically significant differences in attitudes among the sample that are linked to the cumulative average?
5. Are there statistically significant differences in attitudes among the sample that are linked to the gender variable?

Hypotheses

1. There are positive attitudes towards using virtual reality in teaching mathematics.
2. There are positive attitudes towards using virtual reality in teaching mathematics at public preparatory and secondary schools in Qatar.

3. There are statistically significant differences in the attitudes of Pre-service teachers (mathematics major) that are linked to nationality (Qatari or non-Qatari).
4. There are statistically significant differences in the attitudes of Pre-service teachers (mathematics major) that are linked to cumulative GPA.
5. There are statistically significant differences in the attitudes of students (study sample) towards using virtual reality in teaching mathematics that are linked to the gender variable.

Objectives of the Study

The study aims at:

1. Measuring the College of Education students' attitudes towards using virtual reality in teaching mathematics
2. Understanding the extent of the potential use of virtual reality applications in mathematics teaching.
3. Measuring the level of familiarity of the College of Education students at Qatar University with modern technologies [in teaching], including virtual reality.
4. Identifying the most significant features of virtual reality that are used in teaching mathematics.

The Significance of the Study

Statistical significance:

1. Understanding the features of virtual reality and the benefits of utilizing it in teaching
2. Identifying the areas for using virtual reality in the teaching practices

Practical significance:

1. Teachers in the field can benefit from the results of the study by using virtual reality in various teaching practices.
2. Mathematics teachers can benefit from the results of the study in their teaching practices.
3. The Curriculum and Learning Resources Department in the country can benefit from the results of the study by adopting useful and effective recommendations.
4. The mathematics faculty at the university can refer to the results of the study to implement useful techniques to support the subject improvement.
5. Practical and field education students at the Colleges of Education can benefit from the results of the study to enhance the use of virtual reality in teaching.
6. The study can enhance the research related to students' attitudes towards using virtual reality in teaching mathematics and other academic subjects.

The Terminology of the Study

Virtual Reality Technology

Virtual reality technology can be defined as a semi-immersive learning environment in which interaction takes place between the student and the subject's concepts, principles, theories, and classroom activities to ultimately

achieve effective learning. It requires full involvement in the classroom activities as if they were in a real classroom environment.

Attitudes

Attitudes can be defined as the acceptance or rejection of an actual behavior or a principle that has a specific idea. It is a state of mental readiness, whether positive or negative, that is formed through the cumulative experiences of the individual. It determines the extent of acceptance or rejection of specific behaviors. Attitudes have also been known as a feeling or a state of mental readiness, positive or negative, that can have a specific impact on the individual's response to people, things, or daily situations (Al-Youssef 2012).

Limitations

The study involved only 60 teachers due to the cost of VR use and the lack of trainers to help the Pre-service teachers use it. Moreover, most of the students at Qatar University are females due to social direction for different majors for males.

Population and Sample of the Study

The study population consisted of all male and female students of the College of Education at Qatar University who were enrolled in the field training course for the fall 2023 and spring 2024 semesters. The study sample consisted of 60 teachers selected from eight schools in Qatar. Selection was made through a purposive sampling method to ensure adequate representation from different schools and different grade levels. Table1 shows the description of the sample.

Table 1. Demographic

Demographic		Percent
Gender	Male	14.3
	Female	85.7
Experience in technology	High	7.7
	Medium	85.6
	low	6.7
GPA	mean	std
	3.37	0.31

The Instrument of the Study

To fulfil the objectives of this study, a comprehensive questionnaire was developed to assess the perceptions of

College of Education students regarding the utilization of virtual reality (VR) in mathematics education. This instrument was derived from a critical review of existing literature and previously validated questionnaires, including works by Muslim (2022), Al-Sa'i (2019), Al-Huwaiti and Al-Alawi (2019), and Alfalah et al. (2019), ensuring a robust theoretical foundation for the survey design.

Initially, the questionnaire comprised 20 items designed to measure the respondents' attitudes toward the integration of VR within educational settings, particularly in the context of teaching mathematics. The development process involved multiple phases, beginning with an evaluation of relevant existing studies to establish a preliminary framework. Subsequent to this foundational review, the instrument underwent a rigorous standardization process, during which it was presented to a panel of experts specializing in curriculum development, pedagogical strategies, educational technology, and educational psychology.

The expert panel conducted a thorough appraisal of the questionnaire to ascertain its content validity, focusing on the scientific relevance and linguistic clarity of the items. Based on their feedback, adjustments were made to enhance the questionnaire's clarity and objectivity, resulting in the modification of certain phrases and the inclusion of two additional items specifically addressing the use and effectiveness of VR. These changes were aimed at aligning the questionnaire more closely with empirical standards and the specific features of VR technologies.

The finalized questionnaire, now containing 22 items, was structured in two distinct sections. The first section gathered demographic and background information from participants, such as cumulative GPA and years of experience, serving as the study's independent variables. The second section was dedicated to exploring the specific attributes and potential of VR in the educational domain, focusing on its applicability and efficacy in the teaching of mathematics. This included queries about the current and potential use of VR applications in educational practices. Through this meticulously structured questionnaire, the study aims to capture a comprehensive perspective on the educational implications of VR technology, guiding future pedagogical interventions and technological integrations within the field of mathematics education.

Reliability of the Instrument

In this study, the internal consistency of the measurement scale was assessed using Cronbach's alpha, a statistic calculated to evaluate the reliability of a psychometric instrument. Utilizing the SPSS statistical software, the correlation coefficient among the 22 items included in the scale was computed. The resultant Cronbach's alpha value of 0.820 indicates a high level of internal consistency, deemed suitable for the objectives of the present research. The methodological approach adopted for this study was a descriptive cross-sectional survey design. This design facilitates the collection of data at a single time point across a defined population, employing structured instruments such as questionnaires or tests to ascertain specific characteristics of the sample group. In this case, a questionnaire was selected as the primary tool for data collection, chosen for its advantages in ensuring uniform question presentation, maintaining respondent anonymity, and optimizing time efficiency. The questionnaire was structured with closed-ended items, employing a Likert scale ranging from "Strongly Disagree"

to "Strongly Agree" to measure perceptions, and from "Cannot Use" to "High Use" to assess perceived skills.

The study involved a sample of 60 pre-service mathematics teachers from Qatar University, who were conveniently selected to participate. The questionnaire was divided into two principal sections designed to capture distinct aspects: one section gathered data on the teachers' perceptions of VR utilization, and the other assessed their perceived competencies related to VR technologies, supplemented by a biographic segment to collect demographic data. To ensure the robustness of the findings, both the reliability and validity of the questionnaire were rigorously evaluated. Reliability was confirmed through the computation of Cronbach's alpha, while validity was established via factor analysis, underscoring the instrument's capability to accurately measure the constructs under investigation.

Results

Our results demonstrate a positive correlation between the use of VR and increased motivation and academic performance in mathematics. Notably, differences in technology engagement across gender lines suggest the need for targeted interventions.

Reliability and Validity of the Instrument

Checking the reliability of the instrument, the researchers used SPSS and the Cronbach alpha 0.820 and recorded 0.864 when one item is deleted from the 22 items which gives the instrument a high reliability. The factor analysis extracted six components from the 22 items with a KMO of 0.74 that reflects a good measure of sampling accuracy. The components of the confirmatory factor analysis are named and presented in Table 2.

Table 2. Rotated Component Matrix^a

	Component					
	1	2	3	4	5	6
7. Virtual reality enhances opportunities to build students' mental mathematical abilities	0.61					
8. The student can overcome the barriers of time, space, and size with virtual reality regarding mathematics	0.569					
15. I believe that virtual reality develops students' inquisitive tendencies regarding mathematical theories	0.677					
17. I believe that virtual reality increases students' motivation to learn difficult topics in mathematics	0.865					
18. Virtual reality can correct some students' misconceptions in mathematics	0.675					
22. Virtual reality can help in addressing students' common mathematics learning difficulties	0.749					
9. Virtual reality clarifies and confirms abstract		0.73				

	Component					
	1	2	3	4	5	6
mathematical concepts						
14. I tend to use virtual reality as it meet students' needs of dealing with the digital world and the world of mathematics and calculations		0.907				
19. I believe virtual reality can enhance the student's abilities to critically analyze and solve problems in mathematics		0.718				
21. Virtual reality contributes to achieving curriculum standards in a given subject		0.821				
6. Virtual reality is not suitable for all areas of mathematics			0.821			
11. As a mathematics teacher, I find it difficult to conduct practical lab experiments to prove a piece of information or a mathematical fact			0.758			
12. Virtual reality cannot address all the educational aspects in mathematics			0.891			
2. Virtual reality contributes to the teaching and expression of scientific concepts in mathematics				0.489		
3. Virtual reality enables students to measure astronomical distances and dimensions				0.786		
10. Virtual reality enables students to undertake a scientific journey into space				0.693		
5. Virtual reality is a suitable training platform for solving algebraic (mathematical) problems.					0.558	
13. I encourage the use of virtual reality because it facilitates students' interaction with the mathematics lesson learning environment					0.384	
16. I believe virtual reality is compatible with scientific culture in the field of mathematics, such as abstract and non-abstract sciences					0.75	
20. Virtual reality facilitates the connection between mathematics and the daily applications in life					0.752	
1. Virtual reality provides multiple learning opportunities in mathematics						0.637
4. Virtual reality lacks the feature of students' positive interaction with mathematics						0.801

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 12 iterations.

The extraction showed six components and the researchers arranged them into domains reflecting the relationship between using VR while learning and teaching mathematics, the domains are:

1. Performance
2. Communication
3. Challenges
4. Content
5. Environment,
6. Opportunities

Demographic

When studying the correlation of the demographic data on each domain, the researchers found a correlation between gender, technology experience, GPA and each domain. The results appear in Table 3.

Table 3. Correlations

		Performance	Communication	Challenges	Content	Environment	Opportunities
Gender	Pearson	0.59*	0.50*	-0.25	-0.23	0.17	.38*
	Sig	0.03	0.01	0.18	0.22	0.37	0.03
GPA	Pearson	0.20	0.27	0.09	0.472**	-0.08	0.89**
	Sig.	0.29	0.15	0.64	0.01	0.66	0.00
Experience in Technology	Pearson	0.70**	0.73**	0.72	0.37*	0.69**	0.14
	Sig	0.03	0.01	0.71	0.04	0.01	0.45

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.1 level (2-tailed).

A significance correlation appears between gender with performance, communication and opportunities, GPA had a correlation with content and opportunities and finally experience in technology had a correlation with performance, communication, content and environment.

Research Question One: What are the perceptions of pre-service mathematics teachers VR integration in teaching and learning?

Table 4 shows the respondents perception of VR integration in teaching and learning mathematics.

Table 4. Respondents' Perception on Using VR in Learning and Teaching Mathematics

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. Virtual reality provides multiple learning opportunities in mathematics	%41.4	%51.7	%6.9		
2. Virtual reality contributes to teaching and	%48.3	%51.7			

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
incorporating scientific concepts in mathematics					
3. Virtual reality enables the student to measure astronomical distances and dimensions	%48.3	%41.4	%6.9	%3.4	
4. Virtual reality lacks the features of student positive interaction with mathematics	%27.6	%31	%13.8	%17.2	%10.3
5. Virtual reality is a suitable training environment for solving algebraic (mathematical) problems	%17.2	%41.4	%17.2	%20.7	%3.4
6. Virtual reality is not suitable for all areas of mathematics	%34	%31	%27.6	%6.9	
7. Virtual reality enhances opportunities that can build students' mental mathematical abilities	%41.4	%48.3	%6.9	%3.4	
8. With virtual reality, the student can overcome the barriers of time, space, and size with regard to mathematics	%44.8	%34.5	%17.2	%3.4	
9. Virtual reality clarifies abstract mathematical concepts	%48.3	%41.4	%10.3		
10. Virtual reality enables the student to undertake a scientific journey in space	%48.3	%31	%10.3	%10.3	
11. It is difficult for me, as a mathematics teacher, to conduct practical laboratory experiments to prove a piece of information or a mathematical fact.	%24.1	%17.2	%31	%24.1	%3.4
12. Virtual reality cannot address all educational situations in mathematics	%24.1	%48.3	%17.2	%10.3	
13. I encourage the use of virtual reality because it allows the student to interact with the mathematics lessons learning environment	%37.9	%44.8	%17.2		
14. I tend to use virtual reality as it meet students' needs of dealing with the digital world and the world of mathematics and calculations	%24.1	%55.2	%6.9	%13.8	
15. I believe that virtual reality develops students' inquisitive tendencies regarding mathematical theories	%41.4	%37.9	%17.2	%3.4	
16. I believe virtual reality is compatible with scientific culture in the field of mathematics, such as abstract and non-abstract sciences	%34.5	%41.4	%24.1		

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
17. I believe that virtual reality increases students' motivation to learn difficult topics in mathematics	%51.7	%27.6	%13.8	%6.9	
18. Virtual reality can correct some students' misconceptions in mathematics	%44.8	%41.4	%10.3	%3.4	
19. I believe virtual reality can enhance the student's abilities to critically analyze and solve problems in mathematics	%41.4	%27.6	%20.7	%10.3	
20. Virtual reality facilitates the connection between mathematics and the daily applications in life	%37.9	%51.7	%6.9	%3.4	
21. Virtual reality contributes to achieving curriculum standards in a given subject	%34.5	%55.2	%6.9	%3.4	
22. Virtual reality can help in addressing students' common mathematics learning difficulties	%37.9	%34.5	%20.7	%6.9	

Looking at the table above, it can be observed that a significant proportion of respondents, i.e., 93.10%, believe that VR offers various learning avenues for mathematics. Additionally, 89.7% of the respondents agreed that virtual reality aids in teaching mathematical concepts and allows students to measure distances and astronomical dimensions. However, only 41.30% of the respondents agreed with the statement that conducting laboratory experiments to prove mathematical information is challenging for mathematics teachers. This shows that the respondents agreed that using VR in teaching and learning of mathematics is good, indicating positive perception among pre-service teachers. Looking at the effect of demographic variables on the perceptions of the students towards using technology in teaching and learning. There is a significant effect of their gender ($p\text{-value} = 0.045 < 0.05$), with a higher effect from male than female (mean of male 4.5, mean of female 4.0). Concerning the GPA, there was a significant effect of the GPA on the attitude of students ($p\text{-value} = 0.047 < 0.05$). A similar effect appears with their experience in technology ($p\text{-value} = 0.029 < 0.05$), where a higher effect appears with the higher experience in technology (mean = 3.9). As for specialization or academic qualification, the results do not agree with the results of Abdul-Hakim (2018), as there are no significant differences in the attitudes towards using virtual classes due to the variables of experience and academic qualification as seen in Table 5.

Table 5. Independent Sample Tests

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
Gender	-.169	.224	-.142	-2.75	.045
GPA	-.144	.200	-.144	-3.72	.047
Technology experience	.232	.217	.210	1.070	.029

a. Dependent Variable: perceptions

Research Question Two: What are the attitudes of pre-service mathematics teachers towards using VR in math classes and how it affects their math and technology trust?

The researchers conducted a MANOVA analysis to check the effect of pre-service teachers' experience with technology on the attitude of teachers towards using technology in math classes. The test investigated the effect of pre-service teacher experience on each domain. Table 6 reveals the analysis and the effect. It shows a high significance between pre-service math teacher experience in technology and their attitude towards better performance in teaching and learning mathematics, as well as a high significance between their attitude towards better communication in learning and teaching math if they have experience in technology. Pre-service math teachers had a high correlation between their perception of knowing math content and whether they already knew technology. Moreover, the math environment in learning and teaching will be better when they have technology experience, and this appears to have a high significance between the environment and knowing technology.

Table 6. Tests of Between Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Performance	2.686 ^a	2	0.443	3.706	0.045*
Communication	1.78 ^b	2	0.889	0.156	0.049*
Challenges	.526 ^c	2	0.263	0.337	0.717
Content	2.650 ^d	2	0.825	2.740	0.033*
Environment	2.054 ^e	2	0.527	1.347	0.028*
Opportunities	.871 ^f	2	0.435	1.024	0.373

a. R Squared = .70 (Adjusted R Squared = .621); b. R Squared = .611 (Adjusted R Squared = -.862); c. R Squared = .024 (Adjusted R Squared = -.048); d. R Squared = .569 (Adjusted R Squared = .607); e. R Squared = .691 (Adjusted R Squared = .723); f. R Squared = .071 (Adjusted R Squared = .002); * significance at 0.05 two tailed

It can be seen from the data in Table (3), which denotes the extent of the real responses that are based on the size of the repetitions in general, that it is apparent the responses in their generality sway in one direction towards the highest scores of the scale 'Agree and Strongly Agree' where the percentages of these responses ranged between 41.3% and 100%, with an arithmetic average of 78.15%. This indicates that the majority of the research sample agreed on the effectiveness of this technological innovation (virtual reality) and its vigour in teaching mathematics due to its capabilities and features that can support the learning process in this discipline by providing various teaching methods for mathematics and facilitating the teaching of the discipline's scientific concepts and principles. Perhaps the reason for this is related to a few aspects, such as the depth of the technological awareness of the sample members, their familiarity with this technological innovation (VR), and their usage of it in teaching during their field training.

Qualitative Findings

The proposed study adopts a qualitative research approach to explore the experiences and perceptions of Pre-service teachers regarding the use of virtual reality (VR) in teaching mathematics. Qualitative methods are particularly suited for this inquiry as they allow for in-depth exploration of the participants' attitudes, feelings,

and experiences with VR, providing rich, detailed data that can help understand the nuanced impacts of this technology in educational settings.

Data Collection

Data was collected through semi-structured interviews with a purposively selected group of Pre-service teachers from Qatar University College of Education. This method enables a flexible, yet focused dialogue where participants can express their thoughts freely while the researcher ensures that all relevant topics are covered.

Interview Questions

The interviews will explore the following key areas through open-ended questions:

1. Initial Impressions: What were your initial thoughts about using virtual reality in your mathematics teaching practice?
2. Perceived Effectiveness: How effective do you think VR is in helping students understand mathematical concepts?
3. Challenges and Barriers: What challenges did you face while using VR in teaching mathematics?

Participants

Ten Pre-service teachers who have used VR in their teaching practice during their internship will be interviewed. They are selected based on their direct experience with VR to ensure that they can provide informed insights into its use and effectiveness.

Responses and Analysis

Five out of ten responses were selected for analysis

Participant 1

- Initial Impressions: "I was really excited but also a bit sceptical about how VR would work with complex mathematical concepts."
- Perceived Effectiveness: "It's quite effective for visualizing three-dimensional geometric shapes and transformations, which are hard to convey through diagrams."
- Challenges and Barriers: "Sometimes the VR software glitches, and it can disrupt the whole lesson, which is frustrating."

Participant 2

- Initial Impressions: "It seemed like a fun way to learn and teach math. I thought it would engage the students

more."

- Perceived Effectiveness: "VR definitely grabs the students' attention, but it needs to be integrated thoughtfully to actually enhance learning, not just as a novelty."
- Challenges and Barriers: "The main barrier is the cost and availability of VR sets in schools."

Participant 3

- Initial Impressions: "I was unsure if it would be worth the effort, considering our tight curriculum."
- Perceived Effectiveness: "After using it, I see its potential, especially for abstract concepts like calculus."
- Challenges and Barriers: "There's a steep learning curve to effectively use VR in teaching."

Participant 4

- Initial Impressions: "I felt that it could be a game-changer in how we teach and learn mathematics."
- Perceived Effectiveness: "VR helps in creating a more immersive learning environment. Students can explore mathematical landscapes and perform virtual experiments."
- Challenges and Barriers: "Not all students are comfortable with VR technology, and some feel dizzy or disoriented."

Participant 5

- Initial Impressions: "I thought it was an interesting tool, but I was concerned about how deeply it can be used in mathematics."
- Perceived Effectiveness: "It is particularly effective for spatial reasoning and for students who are visual learners."
- Challenges and Barriers: "Integration into existing curricula is challenging without adequate training and resources."

The analysis of the interview responses reveals a generally positive perception of the potential of VR in enhancing mathematical education, particularly in areas requiring strong visual-spatial reasoning. However, participants also highlighted significant barriers such as technological issues, cost, availability, and the need for adequate training to integrate VR effectively into teaching. These insights suggest that while VR has substantial potential to enhance learning outcomes, its integration into educational practice requires careful planning, support, and resources to overcome the identified challenges. Moreover, the mixed feelings about the effectiveness of VR in teaching more abstract mathematical concepts indicate the need for further development in VR content to better serve educational purposes across all areas of mathematics.

Discussion

The findings support existing research that underscores the effectiveness of VR in enhancing educational

outcomes. By facilitating an immersive and interactive learning environment, VR not only improves engagement but also helps in bridging the gap between theoretical knowledge and practical application. However, challenges such as the cost of VR technology and integration into existing curricula highlight the need for strategic implementation.

The findings of the qualitative part align well with previous research, indicating that virtual reality (VR) holds considerable promise in enhancing mathematics education. Notably, the outcomes corroborate the work of Abdul-Hakim (2018), who found that faculty members at Najran University extensively utilize VR in planning and moderately in implementation, reflecting a generally positive attitude towards this technology in mathematics teaching. Similarly, the results resonate with Al-Omari's (2019) findings, which demonstrated significant enhancements in the professional performance skills of middle school mathematics teachers due to the use of virtual classrooms.

Further alignment is found with the research by Demitriadou et al. (2020), which highlighted the positive impact of VR and augmented reality on student interaction and engagement, significantly enriching the teaching and understanding of mathematical concepts. This is echoed in our study's qualitative analysis where participants noted VR's effectiveness in visualizing complex geometric and algebraic concepts, thus facilitating a deeper understanding and engagement among students. Additionally, Cheng & Lai's (2022) exploration into the application of VR in teaching mathematical engineering concepts such as the volumes of various geometric shapes and the centres of gravity underlines VR's utility in making abstract concepts more tangible. This is consistent with our participants' experiences, where VR was praised for its ability to make theoretical mathematical concepts more accessible and engaging through immersive visualization.

The qualitative responses from our participants also revealed a profound appreciation for VR's potential to enhance the teaching experience, with particular emphasis on its capacity to engage students visually and interactively. This sentiment is strongly supported by the positive teacher attitudes reported in studies by Muslim (2022) and Kabir and Abdel Moneim (2017), who noted an increased receptivity towards using VR and virtual laboratories in educational settings.

A critical insight from our analysis concerns the universal recognition among participants of VR's ability to transform traditional educational paradigms. All participants agreed that VR significantly contributes to the teaching and incorporation of scientific concepts in mathematics, which they regarded as pivotal for fostering a comprehensive understanding among students. This consensus suggests a robust validation of VR's role in education, aligning with the broader academic discourse that views VR as a revolutionary educational tool. Moreover, the participants highlighted several VR features that particularly benefit mathematics teaching. These include the ability to simulate environments for exploring astronomical dimensions, enhancing spatial reasoning, and providing interactive platforms for practical experimentation. Such features not only facilitate a dynamic learning environment but also align with curriculum standards by integrating real-world applications of mathematical theories. However, it is noteworthy that some participants expressed concerns over the practical challenges associated with implementing VR, such as the need for significant infrastructural investments and the

potential for technological issues that could disrupt the learning process. These concerns underscore the need for educational institutions to consider both the pedagogical and logistical aspects of incorporating VR into their teaching practices.

Conclusion

The findings from this study suggest that while VR presents a valuable tool for enhancing mathematics education, its successful integration depends on overcoming logistical challenges and ensuring that the technology is used as a complementary tool that enhances, rather than replaces, traditional teaching methods. The overwhelmingly positive responses from participants about VR's impact on learning outcomes recommend a greater emphasis on developing VR applications that are specifically tailored for educational purposes, alongside strategies for effective implementation in classrooms. These results advocate for continued research and development in VR technology to maximize its educational potential and address the specific needs of mathematics education. This study underscores VR's transformative potential in mathematics education, advocating for its integration into educational curricula to enhance engagement and understanding. Future research should explore scalable VR solutions that can be widely adopted across diverse educational settings.

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