Pre-Service Teachers' Readiness and Perceptions towards Integrating Virtual Reality into School Mathematics Teaching in Malaysia

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ABSTRACT

Virtual Reality (VR) has emerged as a promising educational technology that can enhance the teaching and learning of mathematics, particularly for abstract and spatial concepts. However, the successful integration of VR in schools depends largely on future teachers' readiness and perceptions. This study aimed to explore the readiness and perceptions of pre-service teachers from Private Higher Education Institutions in Malaysia towards using VR in school mathematics teaching. A qualitative research design was employed using semi-structured interviews involving 12 purposively selected pre-service mathematics teachers. The interview data were transcribed verbatim and analysed using thematic analysis with the assistance of NVivo software. The findings revealed two major themes: Readiness to Use VR and Perceptions of VR Use. Participants generally demonstrated positive attitudes towards VR and believed that it could improve students' understanding of abstract mathematical concepts, increase motivation, and enhance classroom engagement. However, their readiness to implement VR was influenced by training opportunities, technological confidence, infrastructure availability, pedagogical planning, and institutional support. Participants also viewed VR as a supplementary teaching tool rather than a replacement for conventional instruction. The study contributes to the limited literature on immersive technology adoption among Malaysian pre-service teachers in private higher education settings. The findings suggest that teacher education institutions should provide structured VR training, practical exposure, and adequate technological support to prepare future teachers for meaningful integration of VR in mathematics classrooms.

Keywords: Virtual Reality, pre-service teachers, mathematics teaching, readiness, perceptions, teacher education, Malaysia

INTRODUCTION

Virtual Reality (VR) has increasingly become an important educational technology because it enables immersive, interactive, and three-dimensional learning experiences that can support students' engagement, motivation, conceptual understanding, and spatial reasoning, particularly in subjects that require abstract visualisation such as mathematics (Negara & Siagian, 2024; Dito et al., 2025; Chong et al., 2025). In school mathematics teaching, topics such as geometry, three-dimensional shapes, transformations, coordinates, measurement, and spatial relationships are often difficult for students to understand through conventional two-dimensional diagrams and teacher-centred explanation alone; therefore, VR provides an alternative pedagogical approach by allowing learners to manipulate virtual objects, explore mathematical structures, and experience abstract concepts in a more concrete and meaningful way (Alkaabi et al., 2025; Negara & Siagian, 2024). Beyond student learning, VR has also gained attention in teacher education because it can support simulation-based training, classroom practice, pedagogical reflection, and professional confidence among pre-service teachers (Aguilar & Telese, 2020; Figueroa-Flores & Huffman, 2020; Han et al., 2025;

Petko, 2025). Previous studies indicate that pre-service teachers generally perceive VR and mixed-reality technologies positively because these tools can enhance teaching preparation, support experiential learning, improve teaching self-efficacy, and expose future teachers to innovative classroom practices (Aguilar & Telese, 2020; Figueroa-Flores & Huffman, 2020; Park, 2023). However, the effective use of VR in mathematics teaching depends not only on the availability of technology, but also on teachers' readiness, digital competence, pedagogical understanding, perceived usefulness, perceived ease of use, support from institution, and availability to relevant resources (Carpenter et al., 2023; Chooi et al., 2021; Majewska, 2025). There's also increasing research on immersive technology for teacher training, covering how ready educators are to use it, how well they accept it, and some early hands-on trials, mostly within private universities. What's still missing is research that narrows in on VR specifically, and on pre-service teachers at Private Higher Education Institutions, especially how ready they are to use VR when teaching school mathematics (Chooi et al., 2021; Perinpasingam et al., 2023; Shamsudin & Abdul Majid, 2019). Therefore, this study is important because pre-service teachers are future classroom practitioners, and their readiness and perceptions may influence whether VR can be meaningfully integrated into school mathematics teaching rather than remaining merely a technological innovation without strong pedagogical impact.

Although VR has been widely recognised as a promising tool for improving mathematics learning and teacher education, its practical integration into school mathematics teaching remains uncertain due to several unresolved issues related to teacher readiness, pedagogical competence, technological access, and institutional support (Carpenter et al., 2023; Han et al., 2025; Kumar, 2025). Existing studies have shown that VR can improve students' learning outcomes, motivation, interest, problem-solving ability, geometric understanding, visual thinking, and spatial skills in mathematics education (Negara & Siagian, 2024; Dito et al., 2025; Chong et al., 2025), yet these benefits cannot be fully realised if future teachers lack the confidence, knowledge, training, and pedagogical skills required to use VR effectively in actual classroom settings (Figueroa-Flores & Huffman, 2020; Carpenter et al., 2023; Majewska, 2025). A major concern is that many pre-service teachers may view VR positively but may not have sufficient hands-on experience, access to VR devices, VR curriculum content, or structured guidance on how to integrate VR into mathematics lessons (Kavanagh et al., 2022; Figueroa-Flores & Huffman, 2020; Park, 2023). This is further highlighted in broader findings where teachers who were assigned to specialised or technical subject areas without proper training tend to rely on superficial content delivery and struggle with the practical aspect of teaching, regardless of the subject or technology involved (Sibiya & Khoza, 2025). Research on pre-service teachers in STEM education also found that many participants had limited experience using VR, although they believed it could positively influence teaching and learning (Kavanagh et al., 2022), while other studies reported that VR adoption is constrained by cost, technical limitations, lack of training, digital divide, infrastructure barriers, and difficulties in pedagogical integration (Carpenter et al., 2023; Chong et al., 2025; Kumar, 2025). In Malaysia, the current body of knowledge on immersive technology readiness is mainly focused on educators, Augmented Reality adoption, general technology integration, or micro-teaching practice broadly. There are limited empirical studies for pre-service teachers from Private Higher Education Institutions in relation to VR use specifically for school mathematics teaching (Chooi et al., 2021; Perinpasingam et al., 2023; Shamsudin & Abdul Majid, 2019). This pattern is not just seen in VR adoption. Malaysian teachers navigating other technology transitions, such as the shift to online teaching during the Covid-19 pandemic, have faced similar challenges like insufficient training, low technological confidence, poor internet access, and a lack of institutional support. This suggests that the challenges reflect a broader, recurring feature of technology adoption within the Malaysian education system rather than a challenge specific to any one tool (Nair & Nesamany, 2021). This creates a contextual and empirical gap because the readiness and perceptions of Malaysian private higher education pre-service teachers remain insufficiently understood. If this problem is not examined, teacher education programmes may fail to identify the actual training needs, technological barriers, and pedagogical concerns of future mathematics teachers, which may weaken the meaningful adoption of VR in schools despite its potential to enhance mathematics learning. As such, the present study pursued two questions: (1) How do pre-service teachers describe their readiness to use Virtual Reality (VR) in school mathematics teaching?; (2) How do pre-service teachers perceive the use of Virtual Reality (VR) in school mathematics teaching?

LITERATURE REVIEW

Readiness of Pre-Service Teachers to Use Virtual Reality (VR) in School Mathematics Teaching

The literature generally agrees that Virtual Reality (VR) has strong potential in teacher education, but there is still debate about whether pre-service teachers are genuinely ready to use it in real teaching practice. On one side, VR is presented as a powerful tool for preparing future teachers because it offers immersive, interactive, and repeatable learning experiences that can simulate classroom realities. Han et al. (2025), through a systematic review and meta-analysis, argued that VR has a positive effect on teacher education because it supports procedural rehearsal, reflective practice, and experiential learning. Similarly, Petko (2025) found that repeated exposure to a VR classroom environment increased pre-service teachers' perceived ease of use, suggesting that readiness can improve when teacher candidates are given structured opportunities to practise with VR. These studies support the argument that readiness is not a fixed personal trait, but a developmental process shaped by exposure, practice, and guided experience.

However, another body of literature questions whether positive exposure is enough to claim that pre-service teachers are ready for classroom implementation. Figueroa-Flores and Huffman (2020) found that pre-service teachers believed in the potential of AR and VR, but also recognised the need for more training, resources, and research. This finding complicates the optimistic view of VR readiness because it shows that interest and belief do not necessarily translate into pedagogical preparedness. Kavanagh et al. (2022) also reported that many ICT pre-service teachers had little direct experience using VR, although they perceived it as useful for STEM education. This suggests a gap between technological awareness and instructional readiness. In other words, pre-service teachers may know about VR and may even value it, but they may not yet know how to use it meaningfully in a structured mathematics lesson.

The issue of readiness becomes more complex when infrastructure and context are considered. Carpenter et al. (2023) argued that VR readiness depends not only on individual confidence, but also on external conditions such as access to devices, technical support, cost, curriculum alignment, and pedagogical integration. This is consistent with Nyaaba et al. (2024), who found that pre-service teachers in resource-limited regions responded positively to VR after initial exposure, but identified limited infrastructure, unreliable internet connectivity, and insufficient VR equipment as barriers. These findings challenge studies that focus mainly on attitudes or technology acceptance because they show that readiness cannot be understood only as willingness. Readiness is also structural. A pre-service teacher may be motivated to use VR, but without institutional support, training, and access to suitable tools, that readiness remains incomplete.

In mathematics education, the readiness issue becomes even more specific because VR use must be linked to mathematical concepts, school curriculum, and students' learning difficulties. Studies on VR in mathematics learning show strong benefits. Negara and Siagian (2024) argued that VR can increase students' interest, motivation, engagement, conceptual understanding, and problem-solving ability in high school mathematics. Dito et al. (2025) similarly found that AR and VR applications in mathematics learning improve learning outcomes, spatial skills, visual thinking, problem-solving, and geometric understanding. These studies strengthen the argument that mathematics is a suitable subject for VR because many mathematical concepts require spatial and visual representation. However, these studies focus more on student learning outcomes than on whether future teachers are ready to design, manage, and evaluate VR-based mathematics lessons. This creates an important gap because the success of VR in mathematics classrooms depends not only on the technology's potential, but also the teacher's ability to transform that potential into sound pedagogy.

Shamsudin and Abdul Majid (2019) proposed a VR learning system framework for teacher trainee programmes in Malaysian higher education, indicating early recognition of VR's relevance in teacher preparation. Perinpasingam et al. (2023) then conducted a study at Taylor's University involving pre-service teachers in VR role-playing micro-teaching activities using Engage VR, reporting improvements in confidence, classroom management skills, and instructional efficacy. This study indicates that the integration of immersive technology in Malaysian teacher education programmes is both feasible and

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pedagogically meaningful when structured exposure is provided. Chooi et al. (2021), although focusing on Augmented Reality rather than VR, found that educators' readiness in Malaysian private universities was influenced by perceived usefulness and perceived ease of use. These studies are important because they show that immersive technology readiness is relevant in Malaysian higher education. However, they do not directly examine pre-service teachers from Malaysian Private Higher Education Institutions in relation to school mathematics teaching. Therefore, the local literature remains insufficient for explaining how this specific group understands and experiences readiness for VR-based mathematics teaching.

Taken together, this body of work points to readiness as something built rather than assumed. VR clearly holds promise for preparing future teachers, yet that promise only materialises through sustained exposure and guided practice rather than a single encounter with the technology. Positive attitudes, while common in the literature, should not be mistaken for pedagogical preparedness, since believing VR is useful is not the same as knowing how to design and deliver a lesson with it. What ties these findings together is that readiness rests on both the individual, confidence, competence, and comfort with the tools, and the surrounding system of device access, training opportunities, curriculum fit, and institutional backing. What remains unaddressed is how this plays out specifically for pre-service teachers within Malaysian Private Higher Education Institutions preparing to teach school mathematics. Existing accounts are largely international, centred on teacher education in general, situated within broader STEM contexts, or focused on student rather than teacher outcomes. A qualitative approach is needed to surface the meanings, concerns, and situational realities this specific group brings to VR readiness.

Perceptions of Pre-Service Teachers towards Using Virtual Reality (VR) in School Mathematics Teaching

The literature also shows a broad agreement that pre-service teachers tend to perceive VR positively, but this positive perception is often conditional and accompanied by concerns. Figueroa-Flores and Huffman (2020) found that pre-service teachers perceived AR and VR as valuable tools for teaching and learning because they supported confidence, creativity, and new ways of teaching. Aguilar and Telese (2020) similarly reported that pre-service teachers viewed mixed-reality simulations as positive, meaningful, and relevant to teacher preparation. These studies suggest that pre-service teachers are generally open to immersive technologies when they can see a clear link between VR and professional learning. In this sense, VR is not merely perceived as a technological novelty, but as a possible tool for improving teaching practice.

However, the literature also shows that perception is not always stable. Petko (2025) found that pre-service teachers' perception of a VR classroom application improved after repeated practice, particularly in terms of perceived ease of use. Park (2023) also found that a VR-based EduTech programme improved pre-service teachers' perceptions of educational technology. These findings suggest that perception is shaped by experience. This is important because it challenges any assumption that pre-service teachers' initial views of VR are fixed. A teacher candidate who initially feels uncertain may develop a more positive perception after structured exposure, while a teacher candidate who initially feels excited may become more cautious after facing technical or pedagogical difficulties.

In the context of mathematics teaching, VR is often perceived as valuable because it can make abstract mathematical ideas more visible. Alkaabi et al. (2025) found that pre-service teachers perceived VR positively in mathematics education because it helped visualise complex concepts and increase student engagement. This is supported by Negara and Siagian (2024), who argued that VR creates engaging and realistic learning environments that enhance students' motivation and understanding of mathematical concepts. Dito et al. (2025) further showed that virtual and augmented reality applications in mathematics education can support spatial skills, visual thinking, problem-solving, creative thinking, and geometric understanding. These studies form a strong argument that VR is pedagogically relevant to mathematics, especially when the subject matter involves spatial reasoning, geometry, and visualisation.

Nevertheless, the literature also raises a critical counterargument. Although VR is perceived as engaging and useful, it may also be viewed as costly, technically demanding, and difficult to integrate into normal classroom practice. Kavanagh et al. (2022) found that pre-service teachers recognised VR's potential in

STEM education but raised concerns about cost, distraction, and possible isolation from the real world. Carpenter et al. (2023) similarly argued that teachers' perceptions of VR are shaped by practical barriers such as technical issues, limited content availability, insufficient training, and curriculum integration challenges. Mouw et al. (2020) also found that perceptions of VR were influenced by realism, authenticity, software quality, equipment issues, and instructor proficiency. These studies show that pre-service teachers' perceptions are not simply positive or negative. Rather, they are negotiated between perceived pedagogical benefits and perceived practical limitations.

This tension is particularly important for school mathematics teaching. On one hand, VR can help students visualise geometric objects, transformations, and spatial relationships more effectively than static textbook images. On the other hand, mathematics teachers must ensure that VR use does not become an entertaining activity disconnected from learning objectives. Chong et al. (2025) argued that immersive technologies can support mathematical visualisation and spatial reasoning, but they also highlighted barriers such as high cost, uneven infrastructure, limited teacher readiness, and inconsistent accessibility design. This suggests that positive perceptions of VR must be examined alongside concerns about pedagogical control, accessibility, and meaningful learning. In mathematics education, the central issue is not whether VR is attractive, but whether pre-service teachers perceive it as instructionally useful, manageable, and aligned with school mathematics learning outcomes.

The literature also reveals a contextual gap. Many studies on VR perceptions are conducted outside Malaysia or focus on general teacher education, STEM education, or mixed-reality simulation. While these studies provide useful evidence, they do not fully explain how Malaysian pre-service teachers in Private Higher Education Institutions perceive VR for school mathematics teaching. The private higher education context is important because pre-service teachers in these institutions may have different levels of exposure, training, institutional support, and access to immersive technologies compared with those in public institutions. Although Chooi et al. (2021) provided Malaysian evidence on immersive technology readiness in private universities, their study focused on AR and educators rather than VR and pre-service mathematics teachers. Therefore, the voices of this specific group remain underrepresented.

Across these studies, a consistent picture emerges of pre-service teachers who view VR as useful, engaging, and relevant to both teacher preparation and mathematics teaching. This view, however, is not simply inherited from awareness of the technology. It is shaped and reshaped through actual hands-on exposure. And the positivity itself is conditional, tempered by concerns over cost, access, technical reliability, curriculum fit, distraction, and teachers' own competence. What has not been sufficiently examined is how pre-service teachers within Malaysian Private Higher Education Institutions interpret VR's usefulness, suitability, and limitations specifically for school mathematics teaching. A qualitative approach is well placed to surface the reasoning, uncertainties, and contextual meaning behind these perceptions, rather than simply confirming that they exist.

METHODOLOGY

Research Design

The study employed a qualitative research design as it allows the researcher to explore deeper meanings, contextual realities, and subjective experiences of participants in a naturalistic and non-reductive manner (Creswell & Poth, 2018). Specifically, a descriptive qualitative design was adopted, which is appropriate when the goal is to provide a comprehensive and straightforward summary of a phenomenon as experienced by participants, using language close to their own accounts (Sandelowski, 2000, 2010).

This study is also grounded in an interpretivist epistemological stance, which states that knowledge is constructed through lived experiences, meanings, and interpretations of individuals rather than through objective measurements. This stance is suitable because the study aims to understand how pre-service teachers make sense of their own readiness and perceptions towards VR, rather than to measure these constructs on a numerical scale.

Participants and Sampling

The target population of this study are pre-service teachers enrolled in mathematics education programmes at Private Higher Education Institutions in Malaysia. From this population, 12 participants were selected as the informants for the study. The number was considered appropriate for a qualitative study of this nature as smaller, purposefully selected samples allow for a deeper exploration and saturated interpretation of participants' experiences (Patton, 2002). Guest et al. (2006) further demonstrated that samples of around 12 participants are generally sufficient to achieve thematic richness in interview-based qualitative studies.

Participants were selected through purposive sampling as this technique allows the researcher to identify participants who had relevant background, experience, or exposure and can provide rich, informative data relevant to the phenomenon studied (Patton, 2002; Merriam & Tisdell, 2016). In this study, the selected informants were required to be enrolled in a teacher education programme majoring in mathematics at a Malaysian Private Higher Education Institution and to have some awareness, exposure, or learning experience related to educational technology, mathematics teaching, and VR-based learning.

Instrument and Data Collection

Data were collected using semi-structured interviews. This method was selected because it allows the researcher to explore participants' experiences in depth while still maintaining flexibility to obtain emerging ideas and follow up on significant responses. The interview questions focused on two main areas: pre-service teachers' readiness to use VR in school mathematics teaching and their perceptions of using VR as a pedagogical tool. The interview protocol was developed based on the research questions and reviewed for alignment with the study's objectives prior to data collection (Kallio et al., 2016). Follow-up questions were used where necessary to obtain clearer explanations regarding their technological confidence, pedagogical preparation, access to resources, perceived usefulness, perceived challenges, and support needs.

The data obtained from the interviews were consented from the participants and transcribed into verbatim transcripts. Verbatim transcription was important because it preserved the participants' original words, expressions, and meanings. The transcripts were then reviewed repeatedly to ensure accuracy and familiarity with the data. Each informant was labelled using codes such as Informant 1 (I1), Informant 2 (I2), and so on to maintain confidentiality and anonymity. The use of verbatim data also strengthened the credibility of the findings because direct quotations from informants were used to support the themes generated during analysis.

Data Analysis

Thematic analysis was selected over other qualitative analysis approaches because it is effective in identifying recurring patterns of meaning across a dataset without requiring a specific theoretical or epistemological commitment (Braun & Clarke, 2006). Alternative approaches such as grounded theory were considered unsuitable, as the aim of this study was not to generate a new theoretical framework from the data, but to explore two clearly defined constructs, readiness and perception, that are already established in the literature. Similarly, phenomenological approaches such as Interpretative Phenomenological Analysis were not appropriate, as they are designed for in-depth analysis of individual lived experience with very small samples, whereas this study sought to identify shared patterns across 12 informants. Narrative and discourse analysis were also considered unsuitable, as the interview data were structured around specific topical questions rather than personal life stories or language use. Thematic analysis therefore offered the most appropriate and flexible approach for addressing the research questions of this study (Braun & Clarke, 2006; Terry et al., 2017).

The analysis began with understanding the transcripts, followed by initial coding (Saldana, 2021), then grouping relevant codes into categories, and development of subthemes, and finally the generation of main themes. The coding process focused on identifying patterns related to readiness and perceptions, such as technological confidence, pedagogical readiness, exposure to VR, perceived usefulness, perceived ease of use, perceived challenges, infrastructure constraints, and training needs. The analysis continued until data saturation was achieved, where no new significant codes, categories, or themes emerged from the interview data. This saturation point indicated that the data were sufficient to address the research objectives and research questions.

This study used the NVivo software to assist the qualitative data analysis process. NVivo was suitable for managing interview transcripts, organising codes, developing nodes, comparing categories, retrieving coded segments, and visualising relationships among themes. The use of NVivo did not replace the researcher's interpretation, but it supported a more systematic, transparent, and organised analysis process. Previous methodological literature has shown that NVivo can improve the efficiency of qualitative data management, support coding procedures, and strengthen the transparency of thematic analysis (AlYahmady & Alabri, 2013; Lopezosa, 2020; QSR International, 2020). The analysis continued until data saturation was reached, the point where no new significant codes or themes emerged from the data (Guest et al., 2020). Saturation was observed after the tenth interview, with the eleventh and twelfth interviews confirming no new themes.

Trustworthiness

To ensure trustworthiness, several strategies were applied. Credibility was supported through verbatim transcription, systematic and repeated coding, and including direct participant quotes in the findings to ground the interpretation in actual data. Dependability was supported by maintaining a clear and documented audit trail of the research process, including interview records, transcription procedures, coding decisions, theme development, saturation notes, and analytical memos. Confirmability was supported by grounding the interpretations in the data rather than the researcher's own assumptions, and by reviewing the alignment between codes, themes, and supporting verbatim extracts at each stage of analysis. Transferability was supported by providing detailed descriptions of the research context, participant characteristics, and methodological procedures, allowing readers to assess the applicability of the findings to similar contexts (Creswell & Poth, 2018).

Ethical Considerations

Ethical principles were observed throughout the entire process. All participants were aware of the research and interview purpose, acknowledged that it was a voluntary participation, and knew of the possibility to withdraw at any time without consequence. Informed consent was obtained from all informants prior to data collection. Confidentiality was maintained by anonymising all participant identifiers using codes rather than names. Audio recordings and transcripts can only be accessed by the researcher. No personal identifying information was included in the data analysis or reporting. The study did not involve any deception, and participants were treated with respect and dignity at all stages of the research.

RESULTS

Table 1. Thematic Coding Table

Main Theme	Open Code	Sample Verbatim Extract	Informant
Readiness to Use VR	Exposure through social media	I have heard about VR through social media, especially YouTube and TikTok.	I1
Readiness to Use VR	Exposure through coursework	I first learned about VR during my educational technology class.	I2
Readiness to Use VR	Understanding VR function	I know that VR can create a virtual environment where students can explore learning content.	I3
Readiness to	Need formal	I still need more training before I can confidently use VR in	I2

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Use VR	training	a mathematics classroom.	
Readiness to Use VR	Need lecturer guidance	I need guidance from lecturers because I am not sure how to design a VR-based lesson.	I4
Readiness to Use VR	Need hands-on workshop	I think hands-on workshops are important so pre-service teachers can practise using VR.	I12
Readiness to Use VR	Facility-based readiness	I am ready to use VR if the school provides enough devices and internet connection.	I8
Readiness to Use VR	Limited implementation	If the facilities are limited, I can only use VR as a demonstration in front of the class.	I8
Readiness to Use VR	VR lesson planning	I would use VR during set induction or group activity to attract students' attention.	I11
Readiness to Use VR	Need institutional training	My institution should provide specific VR training for pre-service teachers.	I12
Perceptions of VR Use	3D visualisation	VR can help students understand 3D shapes because they can see the object from different angles.	I3
Perceptions of VR Use	Abstract concept visualisation	VR helps students understand abstract concepts because they can experience the concept visually.	I5
Perceptions of VR Use	Supports weak learners	Weak students may benefit from VR because they can see the concept instead of only memorising formulas.	I6
Perceptions of VR Use	Active learning	VR can make mathematics more interesting because students are not only listening to the teacher.	I5
Perceptions of VR Use	Increased motivation	I believe students will be more motivated when mathematics is taught using VR.	I6
Perceptions of VR Use	Suitable for geometry	VR is very suitable for geometry because students can explore shapes from different perspectives.	I3
Perceptions of VR Use	Spatial understanding	Geometry topics are easier to teach with VR because students can visualise space and shape.	I6
Perceptions of VR Use	VR as complement	VR should not replace traditional teaching because students still need explanation from the teacher.	I10
Perceptions of VR Use	Student distraction	Students may focus too much on the VR animation and forget the actual mathematics concept.	I7
Perceptions of VR Use	Entertainment over learning	If VR is not controlled, students may enjoy the technology but not understand the lesson.	I10

Table 1 shows the thematic coding process from the interview data. Two main themes emerged: Readiness to Use VR and Perceptions of VR Use. The findings indicate that pre-service teachers were aware of VR, but their readiness depended on training, facilities, institutional support, and lesson planning skills. They also perceived VR positively, especially for visualising abstract mathematics concepts, increasing engagement, and supporting geometry teaching. However, some participants viewed VR as a supporting tool only and raised concerns about possible student distraction.

The thematic analysis of interview data from 12 pre-service teachers generated two main themes: Readiness to Use VR and Perceptions of VR Use. These themes reflect participants' views regarding their preparedness and attitudes towards integrating Virtual Reality (VR) in school mathematics teaching.

Readiness to Use VR

The findings showed that most participants had basic awareness of VR through social media and coursework, but this awareness had not yet translated into confident pedagogical readiness. Across the interviews, readiness emerged as a conditional state rather than a fixed characteristic, dependent on training, technological confidence, infrastructure availability, and institutional support.

Several participants described how their awareness of VR was primarily passive and informal. One participant explained: "I have heard about VR through social media, especially YouTube and TikTok" (I1), while another added: "I first learned about VR during my educational technology class" (I2). Although these participants could describe VR in general terms, most acknowledged that they lacked direct hands-on experience with VR in a teaching context.

The gap between awareness and readiness was most evident when participants reflected on actual classroom implementation. One participant stated: "I still need more training before I can confidently use VR in a mathematics classroom" (I2). Another added: "I need guidance from lecturers because I am not sure how to design a VR-based lesson" (I4). These responses suggest that readiness is not merely about knowing what VR is, but about having the pedagogical skills to use it meaningfully within a mathematics lesson.

Infrastructure was also a significant factor. Participants consistently indicated that their readiness was tied to external conditions rather than personal motivation alone. As one participant explained: "I am ready to use VR if the school provides enough devices and internet connection" (I8), and further noted: "If the facilities are limited, I can only use VR as a demonstration in front of the class" (I8). Institutional support was similarly identified as a key enabler. One participant stated: "My institution should provide specific VR training for pre-service teachers" (I12), while another suggested: "I think hands-on workshops are important so pre-service teachers can practise using VR" (I12).

These findings indicate that pre-service teachers' readiness to use VR in mathematics teaching is developmental and context-dependent. Personal willingness does exist, but it remains insufficient without training, pedagogical guidance, and access to adequate technological resources.

Perceptions of VR Use

Participants generally perceived VR as a valuable and pedagogically relevant tool for mathematics teaching, particularly for topics that require spatial reasoning and visualisation. However, their perceptions were not consistently positive and were troubled by concerns about distraction, classroom management, and the risk of technology overshadowing learning.

The most consistent perception was that VR could help students understand abstract mathematical concepts more effectively than conventional teaching methods. One participant explained: "VR can help students understand 3D shapes because they can see the object from different angles" (I3). Another added: "VR helps students understand abstract concepts because they can experience the concept visually" (I5). A third participant noted the potential benefit for lower-achieving students: "Weak students may benefit from VR because they can see the concept instead of only memorising formulas" (I6). These responses suggest that participants viewed VR as suitable for making mathematical abstraction accessible, which aligns with the broader literature on immersive technology in mathematics education.

Participants also believed that VR could positively affect student motivation and engagement. As one participant stated: "VR can make mathematics more interesting because students are not only listening to the teacher" (I5), and another added: "I believe students will be more motivated when mathematics is taught using VR" (I6). Geometry was specifically mentioned as a topic well suited to VR. One participant noted: "VR is very suitable for geometry because students can explore shapes from different perspectives" (I3), while another observed: "Geometry topics are easier to teach with VR because students can visualise space and shape" (I6).

Despite these positive views, participants also expressed concerns. Most notably, several informants positioned VR as a supplementary tool rather than a standalone method. One participant stated clearly: "VR should not replace traditional teaching because students still need explanation from the teacher" (I10). Concerns about distraction were also raised. One participant warned: "Students may focus too much on the VR animation and forget the actual mathematics concept" (I7), while another added: "If VR is not controlled, students may enjoy the technology but not understand the lesson" (I10).

These findings suggest that pre-service teachers hold a complex and conditional view of VR. They recognise its pedagogical potential, especially for visualisation and engagement, but they also acknowledge that effective VR use requires deliberate teacher control, curriculum alignment, and pedagogical clarity to ensure that technology serves learning rather than replacing it.

Summary of Findings

Overall, the thematic findings indicate that pre-service teachers had positive perceptions towards using VR in mathematics teaching, but their readiness depended on training opportunities, institutional support, and adequate facilities. These results suggest that successful implementation of VR in schools requires both positive attitudes and sufficient pedagogical preparation among future teachers.

DISCUSSION

One notable finding was that participants perceived VR as highly useful for visualising abstract mathematical concepts such as three-dimensional shapes, spatial relationships, and geometry. This echoes previous work reporting that VR can improve conceptual understanding, spatial reasoning, and problem-solving in mathematics education (Negara & Siagian, 2024; Dito et al., 2025), and aligns with Alkaabi et al. (2025), who found that pre-service teachers viewed VR positively because it made difficult mathematical concepts easier to grasp. The present study reinforces the idea that immersive technology carries particular relevance for mathematics, a subject where many learners struggle with abstract representation under conventional teaching methods.

Participants also believed VR could lift student motivation, enjoyment, and classroom engagement, a pattern consistent with earlier findings that immersive environments enhance learner attention, participation, and interest (Han et al., 2025; Petko, 2025). This matters because mathematics is often perceived by students as difficult or uninteresting; the present findings suggest future teachers see VR as a tool capable of reshaping that experience by making lessons more interactive and student-centred.

Despite this enthusiasm, readiness among participants remained conditional rather than assured. Many described needing further training, guidance, and hands-on exposure before they would feel confident using VR in an actual classroom, a pattern that supports Carpenter et al. (2023), who argued that teacher readiness rests on competence and access to support systems as much as on attitude. A similar pattern has been observed outside the VR context entirely: teachers placed in technical subject areas without sufficient training have been found to rely on superficial content delivery, lacking the confidence to move beyond textbook explanation into deeper, practice-based instruction (Sibiya & Khoza, 2025). Figueroa-Flores and Huffman (2020) showed a similar problem, where pre-service teachers valued VR but also flagged the need for further training. The present study adds to this argument by showing that exposure to a technology does not, by itself, produce pedagogical readiness; readiness is something that develops over time.

Alongside these views, participants raised concerns about infrastructure limitations, cost, device availability, and the risk of student distraction, echoing Kavanagh et al. (2022) and Chong et al. (2025), both of whom identified similar barriers around cost, unequal infrastructure, and limited accessibility. Taken together, these concerns confirm that while VR carries clear pedagogical value, its classroom implementation depends on careful planning, sustained teacher control, and adequate technological backing.

The present study contributes to the literature by focusing specifically on pre-service teachers from Malaysian Private Higher Education Institutions, a context that remains underexplored in previous studies.

Much of the earlier literature focused on general teacher education, STEM contexts, or international samples. Limited studies have examined how Malaysian private higher education pre-service teachers understand their readiness and perceptions towards VR in school mathematics teaching. Therefore, this study fills an important contextual gap by providing evidence from future teachers within the Malaysian private higher education setting.

Another contribution of this study is the finding that participants did not perceive VR as a replacement for traditional teaching. Instead, they viewed VR as a supplementary pedagogical tool. This indicates that future teachers still value teacher explanation, written exercises, and guided learning. Such findings extend previous research by suggesting that the most realistic role of VR in school mathematics teaching may be blended integration rather than full technological substitution.

Proposed Model to Fill the Literature Gap

Based on the findings and previous literature, a new conceptual model is proposed to explain the successful integration of VR in school mathematics teaching among pre-service teachers.

Pre-Service Teachers' VR Readiness Adoption Model for Mathematics Teaching

Exogenous Factors (Inputs)

i. Technological Exposure
ii. Training and Guidance
iii. Institutional Support
iv. Infrastructure Availability
v. Pedagogical Confidence

Mediating Factor

i. Readiness to Use VR
ii. Outcome Factor
iii. Positive Perceptions towards VR Integration in Mathematics Teaching
iv. Final Impact
v. Intention to Integrate VR in Future Mathematics Classrooms

Explanation of the Model

The model proposes that pre-service teachers develop readiness through technological exposure, training, institutional support, infrastructure, and pedagogical confidence. Once readiness is strengthened, teachers are more likely to hold positive perceptions of VR. These positive perceptions then influence their intention to integrate VR into future mathematics teaching practice.

It is crucial to note that this model is conceptual and has not been empirically tested yet. It is proposed as a preliminary framework that is derived from the current findings and existing literature. The intention is to guide rather than confirm future research into pre-service teachers' VR readiness and adoption in mathematics teaching.

Gap Filled by the Model

Previous studies often examined:

i. perceptions only

ii. readiness only

iii. student outcomes only

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iv. general technology acceptance

However, limited studies have examined how technological factors, training and guidance, and infrastructure collectively shape pre-service teachers' readiness to use VR, and how this readiness, together with positive perception, contributes to the integration of VR in school mathematics teaching among pre-service mathematics teachers from Malaysian Private Higher Education Institutions.

This model addresses that gap by integrating both personal and contextual readiness factors with future adoption behaviour.

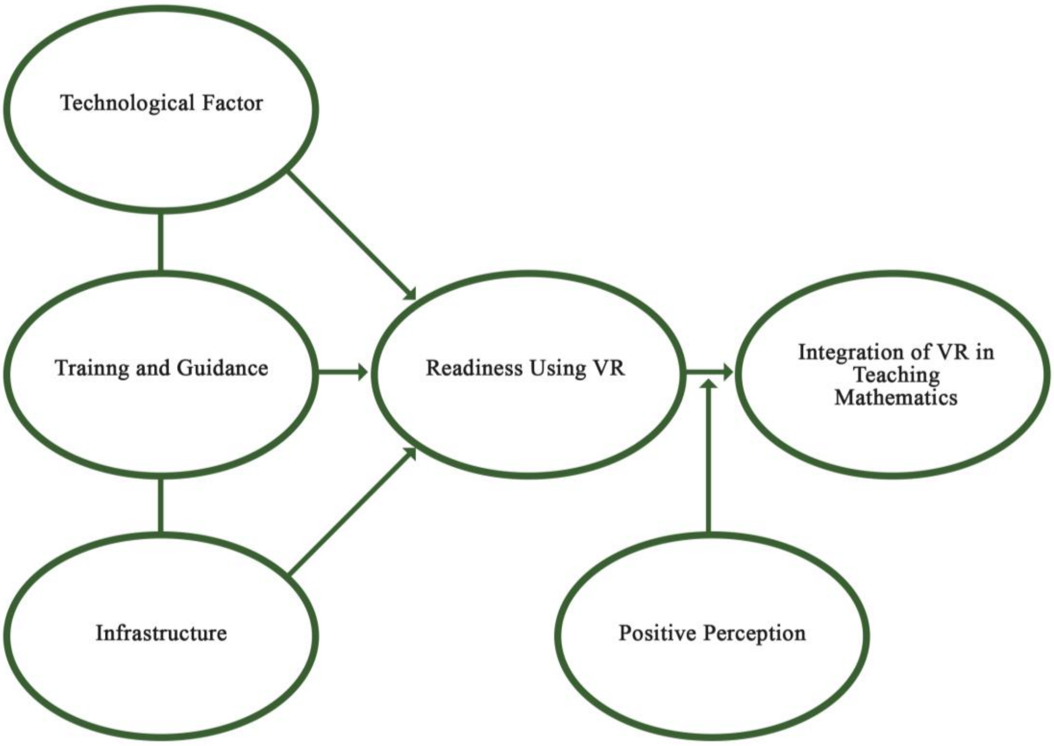

Figure 1. Conceptual Model of Pre-Service Mathematics Teachers' Virtual Reality Integration Readiness Model (VRIRM)

LIMITATIONS

The study has limitations worth noting. First of all, the sample consisted of 12 pre-service teachers from private higher education institutions in Malaysia. Although it is appropriate for the depth sought in a qualitative descriptive design (Patton, 2002; Guest et al., 2006), this does limit the transferability of the findings to pre-service teachers in public institutions or other national contexts. Furthermore, the proposed VR Integration Readiness Model (VRIRM) is conceptual and has not been empirically validated. It is offered as a preliminary framework intended as a starting point for future testing rather than a confirmed explanatory model. In addition to that, as with any qualitative study that is interview-based, the findings reflect participants' self-reported perceptions and readiness rather than observed classroom behaviour. Future research involving larger, more diverse samples across both public and private teacher education institutions, together with empirical testing of the proposed model, would help extend the generalizability of these findings.

CONCLUSION

This study found that pre-service mathematics teachers from Malaysian Private Higher Education Institutions generally showed positive perceptions towards the use of Virtual Reality (VR) in teaching. Participants believed that VR could improve students' understanding of abstract mathematical concepts, increase motivation, and enhance classroom engagement. However, their readiness to implement VR depended on training opportunities, technological confidence, infrastructure, and institutional support. The findings suggest that successful integration of VR in mathematics teaching requires not only positive attitudes, but also adequate preparation and resources. Therefore, teacher education institutions should strengthen VR-related training and practical exposure to prepare future teachers for effective technology integration in schools.

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