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RESEARCH ARTICLE

Mobile Virtual Reality in Mathematics Education: Enhancing Self-Efficacy and Creative Thinking

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Abstract: Mobile Virtual Reality (VR) is increasingly recognized for its potential to make abstract and complex concepts accessible through immersive, portable experiences. In Jordan, students often struggle with mathematics, particularly in topics requiring spatial visualization and the understanding of dynamic processes. This study investigates the role of mobile VR in fostering creative thinking and self-efficacy in mathematics education. A quasi-experimental design was employed with 44 first-year Applied Mathematics students in Amman during the 2024/2025 academic year. Participants were randomly assigned to a control group (n = 21) taught via traditional slide presentations and an experimental group (n = 23) using a mobile VR-based learning module. Statistical analyses, including independent samples t-tests and Mann-Whitney U tests, showed statistically significant differences between the groups ($p < 0.05$). The results indicate that mobile VR instruction significantly enhances creative thinking compared to slide presentations. Additionally, learners in the VR condition exhibited higher mathematical self-efficacy. Effect sizes for creative thinking and self-efficacy were 1.55 and 1.02, respectively, indicating a large to very large effect. Thus, mobile VR-based learning appears to be a powerful tool for improving creative thinking and self-efficacy among mathematics students.

Keywords: creative thinking skills, mobile virtual reality, mathematics education, mobile learning

1 Introduction

The rapid technological advancements of the 21st century are driving a shift toward the "Society 5.0" era, characterized by the deep integration of technology to solve complex problems and improve quality of life (Alfarsi et al., 2021; Ali, 2020). This transformation profoundly impacts education, where technological tools are leveraged to develop core competencies necessary for contemporary success (Alfarsi et al., 2021). However, the integration of technology into teaching practices remains inconsistent, creating a gap between its potential benefits and its actual use in nurturing essential skills (Alhalabi, 2016; Capatina et al., 2017).

Creative thinking, a cornerstone of 21st-century skills, is defined as the cognitive ability to generate novel and effective solutions to problems (Cheng & Tsai, 2013; Dajani & Hegleh, 2019). In the context of pure mathematics, creative thinking is essential for exploring multiple solution pathways, formulating new problems, and making innovative connections between abstract concepts–key activities for advancing mathematical understanding and problem-solving (Bandura, 1997; Sriraman, 2005). Despite its recognized importance, fostering creative thinking in mathematics education remains insufficient (Leikin, 2009; Kaufmann & Schmalstieg, 2003). Students often struggle with non-routine problems requiring advanced cognitive skills (Goff et al., 2018) and face difficulties in articulating original ideas and constructing problems (Silver, 1997).

This shortfall can be attributed to several factors, including learning environments that prioritize passive knowledge reception with limited technological integration, and students' low self-efficacy (Karakose et al., 2022). A significant barrier is the lack of exploratory learning resources that stimulate curiosity and idea generation. Traditional materials often cast learners as passive consumers rather than active contributors, hindering the development of confidence and creative potential (Papert, 1980; Jonassen, 1999; Vygotsky, 1978). There is a pressing need for educational technology that actively immerses students in learning through three-dimensional visualization and interactive discovery. Mobile Virtual Reality (VR) emerges as a promising solution within the framework of mobile learning.

As an accessible and cutting-edge mobile learning technology, VR is highly effective at modeling complex information in an intuitive and engaging manner (Martín-Gutiérrez et al., 2017). By engaging multiple senses, mobile VR creates a sense of presence within a digitally constructed environment (Slater & Wilbur, 1997; Mikropoulos & Natsis, 2011). Its application in education supports cognitive development by integrating scientific concepts, technological tools, and pedagogical strategies (Hew & Cheung, 2010; Tülübaş et al., 2023). Mobile VR transforms learning by offering experiential activities aligned with students' technological familiarity (Hu-Au & Lee, 2017; Jensen, 2017). It enables the simulation, experimentation, and visualization of abstract or inaccessible ideas, providing a dynamic environment that mimics real-world experiences (Dalgarno & Lee, 2010; Freina & Ott, 2015; Radianti et al., 2020; Sutcliffe & Gault, 2004), thereby overcoming physical and practical constraints.

A common challenge in mathematics education is visualizing abstract concepts and dynamic relationships. Mobile VR addresses this by generating virtual objects and interactive simulations through accessible hardware like smartphones and portable headsets, making learning more engaging and effective (Jensen, 2017; Sutcliffe & Gault, 2004). Presenting three-dimensional mathematical objects, such as geometric shapes or function graphs, can significantly enhance student involvement and understanding (Kaufmann & Schmalstieg, 2003).

Rooted in Albert Bandura's social cognitive theory, self-efficacy denotes an individual's belief in their ability to organize and execute actions required to achieve specific performances (Bandura, 1997). It involves regulating emotions and sustaining motivation consistent with one's perceived capabilities (Jensen, 2017; Dalgarno & Lee, 2010). In mathematics, self-efficacy is a crucial determinant of success; students with high self-efficacy demonstrate greater persistence and resilience when confronting challenging tasks (Kaufmann & Schmalstieg, 2003; Pajares & Miller, 1994). Unfortunately, learners often exhibit low mathematical self-efficacy, partly because conventional resources present concepts as static text and equations without providing tangible, interactive evidence. Active learning participation, which mobile VR facilitates, is vital for building the confidence underlying self-efficacy (Schunk & Pajares, 2009; Zimmerman, 2000).

This study is guided by the following research questions:

(1) What impact does mobile VR-based instruction have on students' creative thinking skills in mathematics?

(2) How does learning with mobile VR affect students' self-efficacy in mathematics?

(3) What is the effect size magnitude of mobile VR-based learning for improving students' creative thinking skills and self-efficacy in mathematics?

2 Literature Review

Slide presentations (e.g., PowerPoint, Google Slides) are widely used in education to present information clearly using text, images, and video. Their primary strength lies in structuring information logically, aiding in deconstructing complex subjects (Cheng & Tsai, 2013). For instance, they can effectively illustrate geometric transformations or statistical graphs. Animated presentation software (like Powtoon) has proven effective in improving conceptual understanding (Capatina et al., 2017), while platforms such as Lectora enable interactive exploration (Goff et al., 2018).

However, from a constructivist perspective, slide presentations have significant limitations. They are inherently passive, positioning students as recipients of information rather than active constructors of knowledge (Bandura, 1997). They do not support the investigative and hands-on experiences essential for a deep understanding of mathematics, such as manipulating 3D geometric objects or analyzing dynamic function graphs (Kaufmann & Schmalstieg, 2003). This lack of interactivity underscores the need for more immersive mobile learning media like VR.

Mobile VR is an immersive technology that generates simulated, three-dimensional environments where users can interact via portable devices (Sherman & Craig, 2018; Burdea & Coiffet, 2003; Choi et al., 2016; Lee et al., 2010; Passig et al., 2016). Utilizing head-mounted displays (often smartphone-based) and motion tracking, users experience a sense of "presence" within the digital world (Sherman & Craig, 2018). The educational power of mobile VR stems from its ability to create situated learning experiences, aligning with constructivist and experiential learning theories (Ali, 2020; Alhalabi, 2016; Capatina et al., 2017; Crompton & Burke, 2018). It increases engagement, allows for repeated practice, and enables the safe simulation of complex scenarios (Ali, 2020; Capatina et al., 2017).

In mathematics, mobile VR can create virtual manipulatives, allowing students to deconstruct intricate geometric forms, explore a function's surface, or visualize data in three dimensions (Kaufmann et al., 2005; Bacca et al., 2014; Ibáñez & Delgado-Kloos, 2018; Sırakaya & Alsancak Sırakaya, 2020). This interactive, hands-on approach can demystify abstract concepts, thereby supporting the development of both conceptual knowledge and the self-confidence needed to solve difficult problems (Maas & Hughes, 2020; Pellas et al., 2019).

A central component of social cognitive theory is self-efficacy (Bandura, 1997). It influences how individuals think, feel, and motivate themselves. Key dimensions include:

(1) Performance confidence: Belief in one's capability to use tools and techniques effectively.

(2) Goal attainment belief: Confidence in understanding concepts and improving academic performance.

(3) Assurance in problem-solving: Perseverance and adaptability when facing obstacles (Bandura, 2006; Usher & Pajares, 2008; Zimmerman & Cleary, 2009).

Mobile VR fosters self-efficacy by providing a safe, accessible environment for mastery experiences, a primary source of efficacy beliefs (Bandura, 1993). By repeatedly practicing skills and solving problems in VR without fear of real-world failure, students can build confidence that transfers to standard academic settings (Di Natale et al., 2020; Makransky & Lilleholt, 2018).

The creative thinking process entails generating original ideas, approaching problems from multiple perspectives, and devising inventive solutions (Dajani & Hegleh, 2019; Bandura, 1997). In mathematics, this translates to fluency (producing multiple solutions), flexibility (using different methods), originality (developing unique approaches), and elaboration (constructing detailed solutions) (Dajani & Hegleh, 2019; Runco & Acar, 2012).

Mobile VR serves as an ideal platform for promoting creative thinking. It allows students to experiment with mathematical models, test hypotheses, and visualize outcomes in ways impossible in a traditional classroom. This freedom to explore and manipulate variables encourages divergent thinking and problem identification, core components of creativity (Ali, 2020; Alhalabi, 2016; Plass et al., 2015).

3 Methodology

This research employed a quasi-experimental design. Participants were 150 first-year Applied Mathematics students from a university in Amman. From this population, two intact classes were randomly selected based on their similarity in prior mathematical knowledge (with average pre-test scores of 50 and 51, respectively). These classes were then randomly assigned as control and experimental groups. The final sample consisted of 44 students (Control: n = 21; Experimental: n = 23), as detailed in Table 1.

Table 1 Quasi-Experimental Design

Class	Number of Students	Treatment	Post-test
Control	21	Slide Presentation	Test
Experimental	23	Mobile VR	Test

In the experimental class, participants first received an orientation on the mobile VR equipment (consisting of smartphone-compatible VR headsets and basic controllers). They then interacted with a custom mobile VR application designed for exploring mathematical concepts through interactive simulations (e.g., manipulating 3D graphs and geometric solids). The control class learned the same content using a structured slide presentation delivered by an instructor.

3.1 Data Collection and Instruments

Validated instruments were used to measure creative thinking skills and self-efficacy. Creative thinking was assessed via a test comprising four open-ended, descriptive questions aligned with indicators of fluency, flexibility, originality, and elaboration. Self-efficacy was measured using a 22-item questionnaire based on Bandura's theory, covering three dimensions: confidence in task performance, belief in goal achievement, and belief in problem-solving capabilities (see Table 2 for indicators). The creative thinking instrument demonstrated high validity (r-count > r-table of 0.308) and good reliability (Cronbach's Alpha = 0.779). The self-efficacy questionnaire also showed strong reliability (Cronbach's Alpha = 0.87).

Table 2 Indicators of Self-Efficacy

No	Indicators	Sub-Indicators
1	Confidence in the ability to perform tasks	Confidence in using mobile VR features. Belief in learning effectively with VR.
2	Belief in the ability to achieve goals	Belief in understanding mathematical concepts through VR. Belief in exploring concepts in depth. Belief in improving academic achievement.
3	Belief in problem-solving skills	Belief in overcoming difficulties in understanding materials. Confidence in facing and solving mathematical challenges.

3.2 Data Analysis Techniques

Data were analyzed using SPSS 26. Preliminary normality (Shapiro-Wilk) and homogeneity (Levene's test) tests were conducted. Based on these results, an independent samples t-test was applied to the normally distributed creative thinking data, while the Mann-Whitney U test was used for the non-normal self-efficacy data. The null hypothesis was rejected if the two-tailed significance value was less than 0.05. Effect size was calculated using Cohen's d, with interpretation criteria: $d = 0.2$ (small), 0.5 (medium), 0.8 (large), 1.2 (huge), 2.0 (very huge) (Cohen, 1988).

4 Results and Discussion

4.1 Impact of Mobile VR Learning on Creative Thinking Skills in Mathematics

Post-test results for creative thinking skills are summarized in Figure 1. The mobile VR group outperformed the slide presentation group across all four indicators: Generating Questions (VR: 100, SP: 56), Varied Ideas (VR: 98, SP: 57), Unique Ideas (VR: 77, SP: 63), and Detailed Solutions (VR: 75, SP: 66). Normality and homogeneity tests confirmed that the creative thinking data met parametric assumptions (Sig. > 0.05), as shown in Table 3.

Table 3 Normality and Homogeneity Tests for Creative Thinking Skills

Class	Test of Normality (Sig.)	Test of Homogeneity (Levene Statistic, Sig.)
Control	0.074	2.73, 0.10
Experimental	0.057	

The independent samples t-test results (Table 4) revealed a statistically significant difference between groups ($t = 10.299$, $p < 0.001$). With t-count (10.299) > t-table (2.021) and $p < 0.05$, the null hypothesis is rejected. Mobile VR learning significantly enhances creative thinking skills in mathematics.

Table 4 Independent Samples T-test for Creative Thinking Skills

Class	N	Mean	SD	Sig. (2-tailed)	t-count
Control	21	61.66	8.850	0.000	10.299**
Experimental	23	85.00	6.030		

Note: t-table (df = 42) = 2.021*; * $p < 0.05$; ** $p < 0.001$

4.2 Impact of Mobile VR Learning on Self-Efficacy in Mathematics

Self-efficacy results are presented in Figure 2. The mobile VR group scored higher on all three indicators: Task Performance (VR: 80.28%, SP: 60.95%), Goal Achievement (VR: 80.56%, SP: 56.34%), and Problem-Solving (VR: 80.31%, SP: 55.71%). Tests indicated that the self-efficacy data violated assumptions of normality and homogeneity (Sig. < 0.05), as shown in Table 5.

Table 5 Normality and Homogeneity Tests for Self-Efficacy Data

Class	Test of Normality (Sig.)	Test of Homogeneity (Levene Statistic, Sig.)
Control	0.11	54.10, 0.00
Experimental	0.00	

Therefore, the non-parametric Mann-Whitney U test was applied. Results (Table 6) show a significant difference between groups (U = 135.000, p = 0.010). With $p < 0.05$, the null hypothesis is rejected. Mobile VR learning is significantly more effective at increasing students' mathematical self-efficacy compared to slide presentations.

Table 6 Mann-Whitney U Test Results for Self-Efficacy

Test	Result
Mann-Whitney U	135.000
Z	-2.58
Sig. (2-tailed)	0.010

4.3 Effect Size of Mobile VR on Creative Thinking and Self-Efficacy

Effect size analysis (Table 7) confirms the substantial impact of the mobile VR intervention. Cohen's *d* was 1.55 for creative thinking skills and 1.02 for self-efficacy, both classified as "huge effects" according to applied thresholds (Sherman & Craig, 2018).

Table 7 Effect Sizes for Creative Thinking and Self-Efficacy

Variable	Cohen's *d*	Category
Creative Thinking Skills	1.55	Huge effect
Self-Efficacy	1.02	Huge effect

5 Discussion

The findings of this study provide strong evidence for the efficacy of mobile virtual reality technology in enhancing creative thinking and self-efficacy within undergraduate applied mathematics education in Jordan. The results affirm a significant positive effect, directly addressing the research questions.

The notable superiority of the mobile VR group across all creative thinking indicators aligns with constructivist principles, which posit that immersive, interactive environments foster deeper cognitive processing and the construction of robust mental models (Alhalabi, 2016; Goff et al., 2018; Lampropoulos & Papadakis, 2025). The ability to manipulate 3D mathematical objects in VR appears to facilitate the fluency, flexibility, originality, and elaboration characteristic of mathematical creativity (Dajani & Hegleh, 2019; Runco & Acar, 2012).

Similarly, the significant boost in self-efficacy for the VR group supports social cognitive theory, wherein mastery experiences—safely provided by VR simulations—are a primary source of efficacy beliefs (Bandura, 1997; Bandura, 1993). The interactive, low-stakes practice in VR likely built students' confidence in their mathematical abilities (Di Natale et al., 2020; Makransky & Lilleholt, 2018).

However, these results must be interpreted with balance and caution. The reported "huge" effect sizes ($d = 1.55$ and 1.02), while impressive, emerged from a comparison between a highly interactive, immersive mobile VR experience and a relatively passive slide presentation method. This contrast may, in part, reflect a "novelty effect" or, more fundamentally, the significant disparity in the level of interactivity and learner agency between the two conditions (Clark, 1983; Kozma, 1994). The large effect size likely underscores the power of interactive learning over passive reception, a principle established in educational research, rather than being attributable solely to the VR technology *per se* (Mayer, 2014). Future research should compare mobile VR against other active, technology-enhanced learning strategies (e.g., simulation software, augmented reality) to isolate the unique contribution of the immersive VR medium.

Nevertheless, the practical significance of the findings is considerable. The mobile VR approach, leveraging accessible hardware like smartphones, presents a scalable model for immersive learning within mobile learning paradigms (Crompton & Burke, 2018; Papadakis et al., 2024). This study contributes to a growing body of research advocating for the integration of immersive technologies in STEM education (Kaufmann & Schmalstieg, 2003; Maas & Hughes, 2020; Papadakis et al., 2024), including international work on the educational applications (Lavidas et al., 2022; Lavidas et al., 2022).

These outcomes justify endorsing mobile VR as a potent educational tool. The researcher therefore recommends the following for Jordanian higher education institutions:

(1) Curriculum Integration: Systematically integrate mobile VR modules into introductory and applied mathematics courses, particularly those taught in hybrid or remote formats.

(2) Faculty Development: Implement training programs to equip educators with the skills to design and facilitate effective mobile VR-based learning experiences.

(3) Policy Support: Advocate for investment from the Ministry of Higher Education and university administrations in the necessary mobile technological infrastructure and support further research into the longitudinal impacts of immersive mobile learning.

6 Conclusion

This research conclusively demonstrates that mobile virtual reality technology can significantly improve creative thinking skills and self-efficacy among university students in an applied mathematics context. The empirical evidence, derived from rigorous statistical analyses, strongly supports the theoretical premise that immersive, interactive mobile learning environments yield superior cognitive and affective outcomes compared to traditional, presentation-based instruction.

Despite its demonstrated efficacy, the widespread adoption of mobile VR in Jordan's higher education sector faces challenges, including initial costs, infrastructure requirements, the need for instructor professional development, and concerns regarding digital equity and access. Nonetheless, the potential benefits for student engagement, understanding, and confidence are substantial.

The theoretical implications of this study reinforce constructivist and experiential learning frameworks within digital and mobile education. Practically, the results offer a compelling case for educational leaders and policymakers to strategically invest in and support the integration of mobile VR technologies. Through such actions, universities can enhance the quality and effectiveness of STEM education, thereby better preparing graduates for a technology-driven future. Future research should explore the long-term retention of these skills, the application of mobile VR in other mathematical domains (including pure mathematics), and direct comparisons with other interactive pedagogical tools.

Conflicts of Interest

The author declares that there is no conflicts of interest.

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