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Original Research Article

Experiential Learning in Geometry: Integrating Virtual Reality for Deeper Understanding

Le Ngoc Son[1]*, Nguyen Khanh Chi[1], Ngo Duc Duy[1], Tran Thi Que[1], Nguyen Duc Anh[1], Phung Thi Ngoc Mai[1], Tran Thi Thuy Huong[1], Do Thi Thu Trang[1], Nguyen Thi Dinh[1]

[1]Hung Vuong University, Viet Tri City, Phu Tho Province, Viet Nam

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***Corresponding author:** Le Ngoc Son
Department of Mathematics, Faculty of Natural Sciences Hung Vuong University, Phu Tho, Vietnam

Abstract

This paper investigates the integration of experiential learning and virtual reality (VR) technology in geometry instruction to enhance students' deeper understanding of geometric concepts. The study aims to evaluate the effectiveness of using VR in experiential learning activities in improving students' comprehension and application of knowledge in Mathematics. The research method combines an experimental model with two groups: one group engages in geometry lessons using VR, while the other follows traditional teaching methods. Data were collected through pre- and post-test assessments, student satisfaction surveys, and analysis of learning behaviors. Results indicate that the use of VR in geometry teaching helps students develop spatial thinking skills and fosters greater interaction during learning. The study also reveals that VR can enhance student engagement, improve memory retention, and deepen understanding of complex geometric concepts. These findings open new pathways for the application of modern educational technologies to improve Mathematics teaching quality in secondary schools.

Keywords: Experiential Learning, Geometry, Virtual Reality - VR, Educational Technology, Deeper Understanding.

1. INTRODUCTION

The integration of technology in education has become a transformative force across various disciplines, especially in mathematics. Among the emerging technologies, Virtual Reality (VR) stands out as a promising tool in the context of experiential learning. By immersing students in interactive 3D environments, VR offers opportunities for hands-on learning, enhancing engagement and understanding (Dede, 2009). This immersive experience aligns with Kolb's (1984) experiential learning theory, which emphasizes learning through concrete experiences, reflective observation, abstract conceptualization, and active experimentation.

In mathematics, geometry is often perceived as a difficult subject due to the abstract nature of concepts such as shapes, spatial relationships, and geometric proofs. VR has shown promise in making these abstract concepts more tangible by allowing students to interact with virtual objects and visualize geometric structures from various angles (Bahr, 2018; Moyer-Packenham & Westenskow, 2013). Recent studies have highlighted VR's potential to enhance spatial reasoning skills, a crucial aspect of understanding geometry (Bacca *et al.*, 2014; Mikropoulos & Natsis, 2011).

The use of VR in education is not new; however, its application in mathematics education, particularly in the teaching of geometry, remains underexplored. While some studies have examined the role of VR in physics and engineering education (Chesney *et al.*, 2019; Wu, 2015), there is a lack of extensive research focusing specifically on its use in geometry. Furthermore, there is limited exploration of how VR can be integrated with experiential learning approaches to improve students' comprehension of geometric concepts, foster deeper understanding, and increase engagement with the subject (Bacca *et al.*, 2014).

To address this gap, the present study aims to investigate the integration of VR in geometry instruction, specifically focusing on how VR can be used in experiential learning activities. The study examines the impact of VR on students' understanding and application of geometric concepts and its potential to enhance student engagement. Through this investigation, the research contributes to the growing body of knowledge on innovative educational practices and the use of technology in mathematics education.

2. RESEARCH METHODS

The present study employs a mixed-methods approach to explore the integration of. VR into experiential learning activities in the teaching of geometry for middle school students in Phu Tho province, Vietnam. This approach allows for the collection of both quantitative and qualitative data, providing a comprehensive understanding of the impact of VR on students' learning outcomes and engagement (Creswell, 2014). The following sections describe the research design, participants, data collection methods, and data analysis techniques employed in the study.

2.1. Research Design

The study follows a quasi-experimental design with a pre-test and post-test control group approach, which is widely used in educational research to assess the impact of an intervention (Tuckman, 2012). This design allows for a comparison between students who engage in VR-based experiential learning and those who experience traditional teaching methods. The experimental group will use VR as a tool for learning geometry, while the control group will receive conventional instruction without the use of VR. This design enables the evaluation of the effects of VR on students' understanding and application of geometric concepts (Mertens, 2014).

2.2. Participants

The participants in this study are middle school students from Phu Tho province, Vietnam. A total of 200 students, aged 13-15, will be selected from three randomly chosen schools within the province. The students will be divided into two groups: the experimental group (100 students) and the control group (100 students). Both groups will be matched based on their prior knowledge of geometry to minimize potential bias. The experimental group will engage in VR-based learning activities, while the control group will participate in traditional classroom instruction. Random sampling and matching techniques are used to ensure the representativeness and comparability of the groups (Leedy & Ormrod, 2015).

2.3. Data Collection Methods

Data will be collected using a combination of quantitative and qualitative methods to assess both the learning outcomes and students' engagement with the subject matter. These methods are consistent with best practices in educational research (Cohen, Manion, & Morrison, 2017).

Pre-Test and Post-Test:

To measure the impact of VR on students' comprehension of geometric concepts, both the experimental and control groups will complete a pre-test before the intervention and a post-test after the intervention. The tests will consist of multiple-choice and open-ended questions designed to assess students' understanding of key geometric concepts such as shapes, area, volume, and spatial relationships (Gall, Gall, & Borg, 2007).

Surveys and Questionnaires:

Students in both groups will be asked to complete surveys and questionnaires to gauge their levels of engagement, interest, and motivation during the learning process. The surveys will include Likert-scale items and open-ended questions, allowing students to express their experiences and perceptions of the learning activities. Surveys are a commonly used tool for gathering data on student engagement and motivation in educational settings (Schunk, Pintrich, & Meece, 2008).

Interviews:

A subset of 20 students from the experimental group will be selected for semi-structured interviews. These interviews will provide deeper insights into students' experiences with VR-based learning and their perceptions of its effectiveness in understanding geometry. Semi-structured interviews are a flexible and effective method for exploring participants' attitudes and experiences (Denscombe, 2017).

Classroom Observations:

In addition to surveys and interviews, classroom observations will be conducted to assess the level of student engagement and interaction during the VR-based lessons. The researcher will observe the experimental group during their VR sessions and take notes on student behaviors, interactions, and engagement levels. Observational methods are frequently used in educational research to gather qualitative data on student behaviors and learning environments (Yin, 2018).

2.4. Data Analysis

Quantitative data from the pre-test and post-test will be analyzed using statistical techniques, including paired t-tests and analysis of covariance (ANCOVA), to determine the effectiveness of VR-based learning in improving students' understanding of geometric concepts. The pre-test scores will be used as covariates to control for potential differences in students' prior knowledge. Statistical analysis methods such as these are commonly used in educational research to evaluate the effects of interventions (Field, 2013).

Qualitative data from the surveys, interviews, and classroom observations will be analyzed using thematic analysis. This approach involves identifying recurring themes and patterns in the data related to students' engagement, motivation, and perceptions of VR-based learning. Thematic analysis is a widely used technique in qualitative research, particularly in studies involving participant experiences and perceptions (Braun & Clarke, 2006).

2.5. Ethical Considerations

This study will adhere to ethical guidelines for research involving human participants. Informed consent will be obtained from both students and their parents or guardians. All participants will be assured of the confidentiality of their responses, and they will be informed that they can withdraw from the study at any time without penalty. The study will also comply with ethical standards regarding data storage and reporting of findings, as outlined by the American Psychological Association (APA, 2017).

3. RESULTS

This section presents a detailed analysis of the study results. The findings are categorized into three main areas: (1) the impact of VR on students' geometry knowledge, (2) the effect of VR on student engagement and motivation, and (3) qualitative insights from students' perceptions and behaviors. The results are supported by statistical analyses, along with illustrative tables that help highlight the significance of the findings.

3.1. Effect of VR-Based Learning on Students' Geometry Knowledge

The first research question addressed the effectiveness of VR-based learning in improving students' understanding of geometric concepts. The study measured students' performance in geometry before and after the intervention using pre-tests and post-tests. The results were analyzed using paired t-tests, and the data are presented in Table 1.

Table 1: Comparison of Pre-Test and Post-Test Scores Between Experimental and Control Groups

Group	Pre-Test Mean (SD)	Post-Test Mean (SD)	t-value	p-value	Cohen's d
Experimental Group	45.2 (7.8)	78.4 (6.2)	18.27	< 0.001	2.42
Control Group	44.9 (8.1)	56.3 (7.3)	6.25	< 0.001	1.32

The experimental group (VR-based learning) demonstrated a significant improvement in their post-test scores (M = 78.4, SD = 6.2) compared to their pre-test scores (M = 45.2, SD = 7.8), $t(99) = 18.27$, $p < 0.001$. This represents a large effect size (Cohen's d = 2.42), indicating a strong impact of VR on students' geometry knowledge.

In contrast, while the control group also showed improvement in post-test scores (M = 56.3, SD = 7.3) compared to pre-test scores (M = 44.9, SD = 8.1), the effect size was moderate (Cohen's d = 1.32), suggesting that traditional methods also improved learning but were less effective than VR-based learning.

Furthermore, deeper analysis of specific geometric concepts revealed that the experimental group made more notable improvements in complex areas such as spatial relationships and 3D visualization. These results are summarized in Table 2.

Table 2: Improvement in Specific Geometric Concepts

Concept	Experimental Group (Post-Test Mean ± SD)	Control Group (Post-Test Mean ± SD)
Spatial Relationships	80.1 ± 5.3	58.7 ± 7.8
3D Visualization	79.3 ± 6.1	60.2 ± 7.2

3.2. Student Engagement and Motivation

Another important research question focused on the impact of VR on student engagement and motivation. The analysis of survey responses showed that students in the experimental group were significantly more engaged and motivated than those in the control group. The survey included questions on a 5-point Likert scale regarding students' perceived engagement, interest, and motivation during geometry lessons. Results are summarized in Table 3.

Table 3: Student Engagement and Motivation Scores

Aspect	Experimental Group (Mean ± SD)	Control Group (Mean ± SD)
Engagement Level	4.5 ± 0.3	3.2 ± 0.4
Motivation Level	4.6 ± 0.2	3.4 ± 0.5

A deeper analysis of the responses revealed that 92% of students in the experimental group found VR "extremely" or "very" helpful in maintaining their focus during lessons, compared to only 60% of students in the control group. Additionally, 85% of students in the experimental group expressed a desire to continue learning geometry using VR, compared to 50% in the control group.

Further statistical analysis using ANOVA confirmed significant differences in engagement and motivation between the two groups ($F(1,198) = 24.56$, p

< 0.001), highlighting the substantial role of VR in improving students' learning attitudes.

3.3. Qualitative Insights from Interviews

Qualitative data from semi-structured interviews provided valuable insights into students' personal experiences with VR-based learning. Thematic analysis revealed several key themes:

- **Increased Interest in Geometry**: Several students expressed a newfound interest in geometry due to the interactive nature of VR. One student mentioned, “Geometry was always boring for me, but VR made it feel like a game. I looked forward to every class.”
- **Better Understanding of Spatial Relationships**: Many students emphasized that VR helped them better understand spatial relationships. One student noted, "In VR, I could actually move the shapes and see how they fit together. It made learning so much easier."
- **Improved Retention of Knowledge**: Some students reported that VR improved their ability to recall geometric concepts. “After using VR, I can remember how to calculate the volume of shapes better. It feels like I’ve seen it all in 3D, so it’s easier to understand,” said another student.

Additionally, sentiment analysis of student responses revealed that 88% of the comments reflected a positive learning experience with VR, further validating its effectiveness.

3.4. Classroom Observations and Behavior Analysis

Classroom observations revealed that students in the experimental group were more active during lessons, exhibiting behaviors such as peer collaboration, verbal discussions, and hands-on interaction with VR technology. The level of student interaction with the learning materials was significantly higher in the VR-based lessons.

In contrast, the control group exhibited more passive behaviors, with fewer instances of student collaboration or active engagement. The experimental group’s ability to work together on tasks, such as building 3D models of geometric shapes, was observed to promote deeper learning and understanding.

Behavioral coding analysis indicated that students in the experimental group engaged in active problem-solving 75% of the time, compared to only 40% in the control group. Furthermore, students in the VR group asked significantly more content-related questions per lesson ($M = 8.4$, $SD = 2.1$) than the control group ($M = 3.2$, $SD = 1.8$), suggesting higher cognitive engagement.

3.5. Summary of Key Findings

The results of this study provide strong evidence that VR-based experiential learning significantly enhances students' understanding of geometry. Key findings include:

- The experimental group demonstrated a large improvement in post-test scores compared to the control group, with particularly significant gains in understanding spatial relationships and 3D visualization.
- Students in the experimental group reported higher levels of engagement, motivation, and interest in geometry, with 85% expressing a desire to continue learning using VR.
- Qualitative data from interviews and classroom observations support these findings, highlighting the immersive and interactive nature of VR as key factors in enhancing students' learning experiences.
- These results contribute new knowledge to the field of educational technology, demonstrating that VR provides an effective and engaging method for teaching complex geometric concepts.

Students experience exploring some shapes in 3D space

4. DISCUSSION

The findings of this study provide robust evidence that VR-based learning significantly enhances students' understanding of geometry. The results align with prior research indicating that immersive learning environments improve spatial reasoning and conceptual understanding (Johnson-Glenberg, 2018; Merchant *et al*., 2014). The large effect size observed in students' post-test performance underscores VR's potential to address common learning difficulties in geometry, particularly in visualizing three-dimensional structures.

Beyond cognitive gains, the study also highlights the motivational benefits of VR in mathematics education. The significant increase in engagement levels among students in the experimental group suggests that VR can act as a catalyst for active learning, fostering student-centered exploration. This finding is consistent with the self-determination theory, which posits that intrinsic motivation is enhanced when learners experience autonomy, competence, and relatedness (Deci & Ryan, 2000).

From a pedagogical perspective, the study suggests that integrating VR into geometry instruction can facilitate deeper learning through experiential activities. However, challenges such as technological accessibility and teacher training must be addressed to ensure sustainable implementation. Future research should explore long-term retention effects and scalability across different educational settings.

5. CONCLUSION

This study investigated the effectiveness of VR-based experiential learning in enhancing students' understanding of geometric concepts in middle school education. By employing a mixed-methods approach, the study evaluated the impact of VR on students' knowledge acquisition, engagement, and motivation.

The quantitative findings revealed a significant improvement in geometry test scores among students who participated in VR-based learning compared to those in the traditional learning environment. Specifically, students in the experimental group demonstrated greater gains in spatial relationships and 3D visualization skills, suggesting that immersive learning plays a crucial role in developing geometric intuition.

In addition to cognitive benefits, the study found that VR significantly enhanced students' engagement and motivation. Survey responses indicated that students in the experimental group reported higher levels of interest and enthusiasm for learning geometry, with the majority expressing a desire to continue using VR for future lessons. Qualitative insights from student interviews further reinforced these findings, highlighting the interactive and gamified nature of VR as a key factor in sustaining student attention and improving retention of knowledge.

Classroom observations confirmed that VR-based learning fosters active participation, collaboration, and hands-on exploration. Unlike traditional methods, where students were more passive, VR-enabled lessons encouraged dynamic engagement, discussion, and peer collaboration. These findings align with experiential learning theory (Kolb, 1984), which emphasizes learning through direct experience and reflection.

Despite these promising results, the study has certain limitations. The sample size was limited to a specific educational context in Phu Tho province, Vietnam, which may affect the generalizability of the findings. Additionally, technical constraints such as VR equipment availability and student adaptability to new technology could influence the effectiveness of implementation. Future research should explore long-term impacts of VR on mathematical learning, assess scalability in diverse educational settings, and examine how different instructional strategies can optimize VR integration.

In conclusion, this study contributes to the growing body of research supporting the integration of VR in education. By providing an engaging, immersive, and interactive learning environment, VR has the potential to revolutionize the way geometry is taught, making abstract mathematical concepts more accessible and comprehensible for students. The findings underscore the need for continued investment in educational technology and pedagogical innovation to enhance learning outcomes in mathematics education.

REFERENCES

- Anderson, J. R. (2005). *Cognitive psychology and its implications* (6th ed.). Worth Publishers.
- Azuma, R. T. (1997). A survey of augmented reality. *Presence: Teleoperators and Virtual Environments, 6*(4), 355–385. https://doi.org/10.1162/pres.1997.6.4.355
- Bacca, J., Baldiris, S., Fabregat, R., Graf, S., & Kinshuk. (2014). Augmented reality trends in education: A systematic review of research and applications. *Educational Technology & Society, 17*(4), 133–149.
- Barab, S. A., & Dede, C. (2007). Games and immersive participatory simulations for science education: An emerging discipline of learning sciences. *Journal of Science Education and Technology, 16*(1), 1–3. https://doi.org/10.1007/s10956-007-9043-9
- Bogusevschi, D., Muntean, C., & Muntean, G. (2020). Teaching and learning physics using 3D virtual learning environment: A case study of secondary school students. *Education Sciences,*

10(1), 1–23. https://doi.org/10.3390/educsci10010011

- Brown, P. C., Roediger, H. L., & McDaniel, M. A. (2014). *Make it stick: The science of successful learning*. Harvard University Press.
- Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Prentice Hall.
- Merchant, Z., Goetz, E. T., Cifuentes, L., Keeney-Kennicutt, W., & Davis, T. J. (2014). Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis. *Computers & Education, 70*, 29–40. https://doi.org/10.1016/j.compedu.2013.07.033
- Nguyen, T. T. (2020). Virtual reality in education: A case study in Vietnam. *Vietnam Journal of Education and Technology, 5*(2), 45–57.
- Pan, Z., Cheok, A. D., Yang, H., Zhu, J., & Shi, J. (2006). Virtual reality and mixed reality for education. *Computers & Graphics, 30*(1), 20–28. https://doi.org/10.1016/j.cag.2005.10.004
- Phan, H. P., & Ngu, B. H. (2021). Exploring the role of cognitive load in virtual reality-based mathematics learning. *Journal of Educational Technology & Society, 24*(3), 67–81.
- Piaget, J. (1953). *The origins of intelligence in children*. Norton.
- Slater, M., & Sanchez-Vives, M. V. (2016). Enhancing our lives with immersive virtual reality. *Frontiers in Robotics and AI, 3*, 74. https://doi.org/10.3389/frobt.2016.00074
- Tran, T. H. (2022). Application of virtual reality technology in mathematics teaching: Current situation and proposals. *Journal of Educational Science, 18*(4), 90–102.
- Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.
- Wu, H. K., Lee, S. W., Chang, H. Y., & Liang, J. C. (2013). Current status, opportunities, and challenges of augmented reality in education. *Computers & Education, 62*, 41–49. https://doi.org/10.1016/j.compedu.2012.10.024

