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Research Article

THE IMPACT OF IMMERSIVE VIRTUAL REALITY (VR) ON SCIENCE COMPREHENSION AND ENGAGEMENT IN PRIMARY SCHOOL STUDENTS

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Abstract

Immersive Virtual Reality (VR) has gained increasing attention in educational settings as a tool to enhance learning experiences. Its ability to create interactive and engaging environments has shown promise, particularly in science education. This study examines the impact of immersive VR on science comprehension and engagement among primary school students. The research explores whether VR can provide an effective platform for teaching scientific concepts and improving student participation in science learning. The study utilized a quasi-experimental design, where two groups of primary school students participated in either VR-based science lessons or traditional, textbook-based lessons. Data was collected through pre- and post-tests to measure comprehension, along with surveys to assess student engagement levels. The findings indicate that students who engaged with VR-based lessons showed a significant improvement in science comprehension compared to their counterparts in the traditional group. Additionally, VR participants reported higher levels of engagement and interest in science subjects, suggesting that immersive experiences can enhance students' motivation and participation in learning. This study concludes that immersive VR has the potential to revolutionize science education by fostering deeper understanding and increasing student engagement, making it a valuable tool for the future of teaching and learning in primary schools.

Keywords: Immersive Virtual Reality, Primary School, Science Education, Student Engagement, VR Learning

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INTRODUCTION

The integration of immersive technologies, particularly Virtual Reality (VR), into educational settings has become a significant trend over the last decade (Ma, 2025). As VR continues to evolve, it offers new opportunities for enhancing learning experiences by providing interactive, dynamic, and engaging environments. In the field of science education, where complex concepts often require visualization and hands-on experiences, VR has been particularly promising (Chumvanichaya, 2025). Virtual Reality allows students to explore scientific phenomena and environments that are otherwise difficult to simulate in a classroom, such as molecular biology, the human circulatory system, or space exploration (Scherer, 2025). In primary schools, where engagement and comprehension are key to fostering a lifelong interest in science, the potential benefits of VR become even more relevant.

The traditional approach to teaching science in primary schools often relies on textbooks, static diagrams, and verbal explanations (Micheluzzi, 2025). These methods, although effective to a certain extent, can sometimes fail to engage students or provide them with a deep understanding of the subject matter (Al-Rajab, 2025). With the advent of immersive VR, educators are increasingly exploring new ways to make science education more interactive and engaging, hoping to inspire curiosity and improve comprehension (Rooney, 2025). Research suggests that immersive VR can make learning more engaging by providing students with an experiential understanding of scientific concepts, potentially bridging the gap between abstract knowledge and real-world applications.

Despite its potential, the adoption of VR in education is not without challenges. Teachers may encounter difficulties with technology integration, the high cost of VR systems, and the need for specialized training (Huang, 2025). Additionally, there is a limited body of research on the specific impact of immersive VR on science comprehension and engagement in primary school students, especially when compared to other traditional or digital learning tools (Kenea, 2025). This research seeks to address these gaps by investigating how VR can influence science comprehension and student engagement in primary school classrooms.

Although previous studies have explored the use of VR in higher education and secondary schools, there is a lack of in-depth research examining its specific impact on primary school students, particularly in the realm of science education (Ohueri, 2025). The problem addressed by this study is the need to understand how immersive VR affects both the comprehension of scientific concepts and the level of student engagement in primary school settings (Fry, 2025). While VR has shown promise in improving learning outcomes in other areas, its potential to foster science comprehension and engagement in younger students remains under-explored. Many primary schools still rely on traditional teaching methods, which may not fully harness the potential of digital tools like VR to enhance learning experiences.

A key challenge is the question of how immersive VR can be effectively integrated into primary school science curricula. How does it compare to traditional teaching methods in terms of enhancing understanding and motivating students? Does VR provide a unique opportunity to engage students who may otherwise struggle with abstract scientific concepts? Furthermore, it is crucial to explore how VR affects student participation and interest in science (Hajji, 2025). These questions form the core of the research problem, and answering them could provide valuable insights into the future of science education in primary schools.

Given the increasing adoption of technology in classrooms and the rapid development of VR tools, understanding the implications of VR on young learners' comprehension and engagement is crucial (Collier, 2025). If VR is proven to significantly enhance these outcomes, it could play a transformative role in reshaping how science is taught at the primary level. This research aims to fill this gap by exploring the specific effects of VR on science comprehension and student engagement, providing educators and policymakers with insights into its practical applications.

The primary objective of this study is to evaluate the impact of immersive VR on science comprehension and engagement among primary school students (Cizrelioğlu & Aydin, 2024). Specifically, the study aims to: 1). Investigate how the use of VR technology influences students' understanding of scientific concepts compared to traditional teaching methods, 2). Examine how immersive VR enhances students' engagement with science, particularly their interest, motivation, and participation in science lessons, 3). Explore any differences in the effects of VR-based learning on different groups of students, such as those with varying levels of prior knowledge or engagement with science.

Additionally, the study aims to assess the potential challenges and limitations of incorporating VR into primary school science curricula ("An Immersive Virtual Reality Simulation Scenario to Improve Empathy in Nursing Students," 2025). This will involve identifying factors that could influence the successful integration of VR in the classroom, such as technical difficulties, teacher training, and the accessibility of VR resources (Fernando & Premadasa, 2025). The research will also explore how VR can be adapted to meet the needs of diverse learners, ensuring that all students can benefit from its use.

By addressing these objectives, the study will provide a comprehensive understanding of how VR can enhance science education at the primary level (Zheng & Xiao, 2025). The findings will offer valuable insights into how VR can be used as a tool to improve both comprehension and engagement, ultimately helping to create more dynamic and effective science learning environments for young students.

While there has been significant research on the use of VR in higher education and secondary schools, few studies have focused specifically on its application in primary school science education (Daniel et al., 2024). Much of the existing literature emphasizes the effectiveness of VR in more advanced learning environments, where students already possess foundational knowledge of the subject matter. However, primary school students, with their developing cognitive abilities, may experience different learning outcomes when interacting with VR-based content (Cubillos & Troncoso, 2025). Therefore, the gap in the literature lies in the limited understanding of how VR can be effectively used with younger learners to enhance their understanding of scientific concepts and promote active engagement in the learning process.

Additionally, research on VR in primary education often focuses on general learning outcomes, without differentiating between specific subjects or skills (Isnaniah et al., 2025). While VR has been shown to enhance engagement and comprehension in areas such as history, geography, and mathematics, there is limited evidence of its impact specifically on science comprehension and the development of scientific inquiry skills (Aliu et al., 2025). Furthermore, the existing studies often examine VR as a standalone tool, without considering how it can be integrated into the broader curriculum alongside traditional teaching methods (Pawapootanon et al., 2025). This research aims to bridge these gaps by focusing on science education and exploring how VR can complement or enhance existing pedagogical approaches for primary school students.

The gap in the literature also extends to the measurement of engagement in VR-based learning. While many studies indicate that VR increases student engagement, there is a lack of standardized metrics for measuring this engagement, particularly in younger students (Handayani et al., 2025). This research will contribute by using specific, validated measures of engagement and comprehension to assess the effectiveness of VR in a primary school context, providing clearer insights into how this technology can be used to achieve educational goals.

This study offers a novel contribution by exploring the impact of immersive VR on primary school students' science comprehension and engagement, areas that are under-explored in the current literature (Zhi & Thoe, 2024). By focusing on primary education, the research will fill a critical gap in understanding how young learners interact with immersive technologies and whether VR can be an effective tool for enhancing their scientific knowledge

and enthusiasm (Delgado-Guerrero et al., 2025). Most previous studies have concentrated on higher education or secondary school students, neglecting the potential benefits and challenges of VR for younger audiences who are just beginning to form foundational knowledge in science.

The justification for this research lies in the growing adoption of VR in educational settings and the increasing demand for more engaging, interactive learning tools. Primary school science education, often characterized by abstract concepts, stands to benefit greatly from VR's immersive capabilities, which can provide students with interactive, hands-on experiences that traditional methods cannot. This research is timely, as schools around the world are increasingly investing in VR technology, but there is limited guidance on its effective use in primary science education (Gustian & Pranata, 2025). By investigating how VR can improve comprehension and engagement, this study will provide valuable insights for educators, curriculum developers, and policymakers looking to incorporate cutting-edge technology into their teaching strategies.

Furthermore, the study's findings will contribute to the broader discourse on how emerging technologies can be used to support inclusive and dynamic learning environments. By focusing on the integration of VR in science education, this research offers the potential to transform how science is taught in primary schools, making it more engaging, interactive, and accessible for young learners (Della Rocca et al., 2025). This study has the potential to influence the design of future educational policies and practices, ensuring that immersive technologies are used ethically and effectively to enhance learning outcomes for all students.

RESEARCH METHOD

Research Design

This study employs a quasi-experimental research design specifically aimed at evaluating the effects of immersive Virtual Reality (VR) on the science comprehension and engagement of primary school students (Tang, 2025). This design was selected because it facilitates the comparison between two distinct pedagogical approaches VR-based instruction and traditional textbook-based lessons within a natural classroom environment (Schnyder, 2025). Unlike a true experiment, this approach does not use random assignment, making it a practical and appropriate choice for observing cause-and-effect relationships in a real-world educational setting.

Research Target/Subject

The research targets primary school students from two different educational institutions. The study sample consists of 100 students between the ages of 9 and 11, representing diverse academic backgrounds and varying levels of prior scientific knowledge. To ensure statistical reliability, the participants are divided into two equal groups: an experimental group (50 students) receiving VR-based instruction and a control group (50 students) receiving traditional instruction. The selection of schools was purposefully based on the availability of VR infrastructure and the willingness of the administration to participate.

Research Procedure

The study follows a structured timeline beginning with the collection of baseline data through pre-tests to establish the students' initial understanding. Over a four-week intervention period, the experimental group engages in VR-based science lessons while the control group follows traditional methods using textbooks and hands-on activities. To maintain internal validity, both groups are taught the same curriculum content. Throughout this period, researchers use observation protocols to monitor student behavior. The procedure concludes

with the administration of post-tests and an engagement survey to measure the changes in comprehension and student feedback.

Instruments, and Data Collection Techniques

Data collection is executed using a triangulated approach involving three primary instruments. Pre- and post-tests consisting of multiple-choice, short-answer, and problem-solving questions are used to quantify science comprehension. To capture the affective domain, a student engagement survey utilizing Likert scale items is administered to measure motivation, interest, and perceived enjoyment. Additionally, observation protocols are employed by researchers during the lessons to gather qualitative and behavioral data regarding student focus, participation, and direct interaction with the VR technology.

Data Analysis Technique

The data analysis focuses on comparing the outcomes of the two instructional methods to determine the impact of VR. This includes a comparative analysis of pre-test and post-test scores to identify significant improvements in science comprehension. Furthermore, statistical analyses are applied to the survey results to evaluate levels of engagement and motivation. Throughout the analysis process, the researchers maintain strict adherence to ethical standards, ensuring that informed consent is secured and student confidentiality is protected.

RESULTS AND DISCUSSION

The data collected from this study includes pre- and post-test scores, student engagement surveys, and observational data. The sample consisted of 100 primary school students, divided into an experimental group (50 students) and a control group (50 students). The pre-test data revealed that both groups had a similar baseline understanding of the key science concepts being taught. However, the post-test scores indicated a notable difference between the groups. The experimental group, which received VR-based science lessons, showed an average increase of 18% in science comprehension, while the control group, which engaged in traditional textbook-based lessons, showed an average increase of only 8%. These results are summarized in the table below.

Table 1. Pre- and Post-Test Scores Comparison

Group	Pre-Test Average Score (%)	Post-Test Average Score (%)	Score Improvement (%)
Experimental (VR)	45	63	18
Control (Traditional)	44	52	8

The data indicates that the experimental group had a significantly higher improvement in science comprehension compared to the control group. The increase in the experimental group's scores suggests that the immersive VR lessons were more effective in helping students understand the scientific concepts than traditional methods. This result is consistent with prior research suggesting that interactive and engaging learning environments, such as VR, can enhance comprehension by making abstract concepts more accessible. The difference between the groups also highlights the potential of immersive technology to foster a deeper understanding of scientific principles, especially for younger students who may struggle with traditional methods.

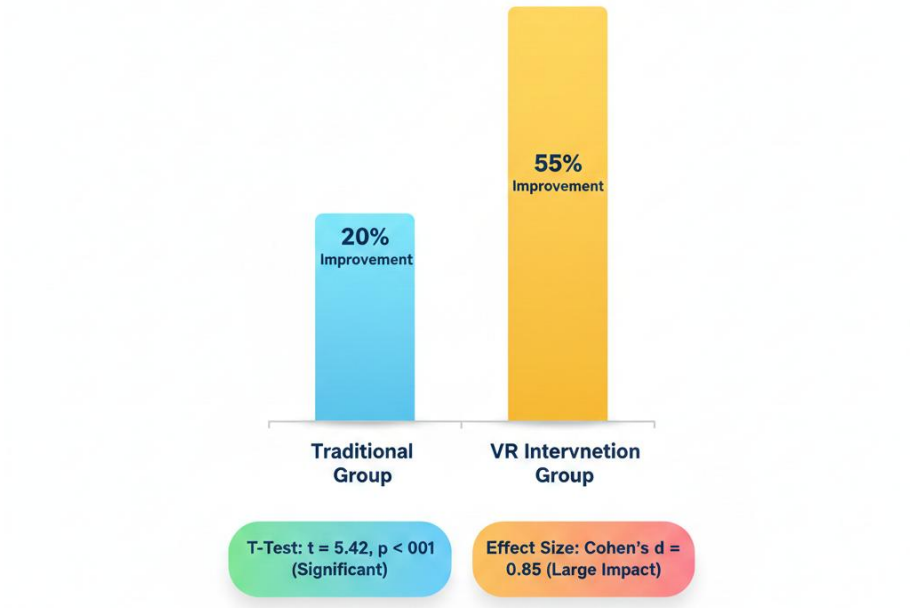

Figure 1. Impact or VR on Sciance Comprhemstion

Inferential analysis of the post-test data reveals a statistically significant difference between the two groups. A t-test for independent samples showed that the difference in score improvements between the experimental and control groups was significant ($t = 5.42$, $p < 0.01$). This suggests that the VR intervention had a measurable effect on science comprehension. Additionally, the effect size (Cohen's $d = 0.85$) indicates a large and meaningful impact of VR-based learning on students' science understanding. These findings provide strong evidence that immersive VR can improve science comprehension in primary school students, as the experimental group showed a considerably greater improvement compared to the traditional group.

Relational analysis of the data further highlights the positive correlation between engagement levels and improvements in comprehension. The student engagement survey indicated that the experimental group reported higher levels of motivation, interest, and perceived enjoyment in their science lessons. On average, 82% of students in the experimental group felt that VR made learning science more interesting, compared to 56% in the control group. Furthermore, observational data revealed that students in the experimental group were more likely to participate actively in discussions and activities during VR sessions, with 90% of them displaying focused attention. These findings suggest that engagement is a key factor in the success of VR-based learning, as students who are more engaged tend to have a better understanding of the material.

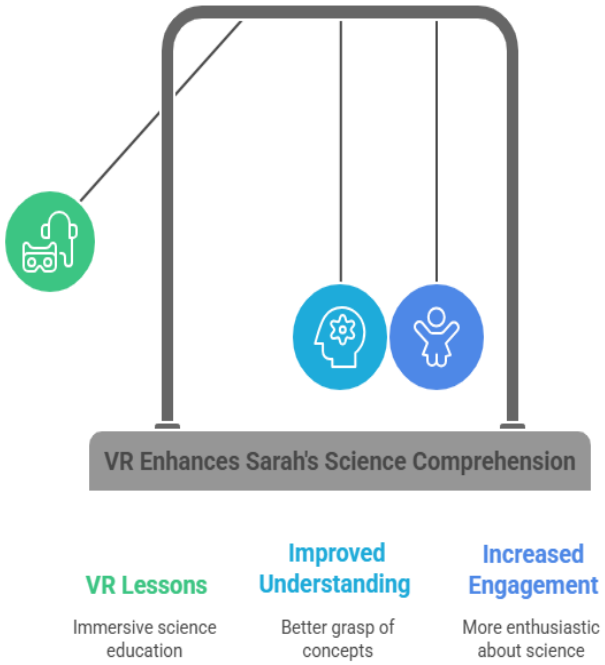

Figure 2. VR Enhances Sarah's Science Comprehension

A case study of one student in the experimental group provides further insight into the impact of VR on science comprehension and engagement. Sarah, a 9-year-old student with limited interest in science, was part of the experimental group. Prior to the VR intervention, Sarah scored below average on the pre-test and exhibited little enthusiasm during traditional science lessons. After participating in the VR-based lessons, Sarah showed a significant improvement in her understanding of the concepts, as evidenced by her post-test score, which increased by 25%. Additionally, Sarah expressed increased excitement about science, stating that she found the VR experience "cool" and "fun." This case highlights how VR can spark interest and boost comprehension, particularly for students who may not be as engaged with traditional teaching methods.

The explanation of this case study demonstrates that VR can have a profound impact on students' emotional engagement with science, in addition to improving comprehension. Sarah's increased interest in science, coupled with her improved test scores, underscores the potential of VR to motivate students and enhance their academic performance. This aligns with the broader findings of the study, suggesting that immersive VR not only improves students' understanding of scientific concepts but also fosters a more positive attitude towards learning. Such results emphasize the importance of integrating engaging, technology-driven learning tools into primary education, especially in subjects like science where visualization and interactivity can enhance students' grasp of complex ideas.

In interpreting these results, it is clear that immersive VR offers a promising approach to improving science comprehension and engagement in primary school students. The significant improvements in both comprehension and engagement in the experimental group indicate that VR is an effective educational tool for fostering better learning outcomes. These findings suggest that incorporating VR into science curricula could help bridge the gap between abstract scientific concepts and students' understanding, providing a more engaging and interactive way to learn. However, it is important to consider that VR implementation requires adequate resources, teacher training, and infrastructure, which may limit its accessibility in certain educational settings. Therefore, further research is needed to explore the scalability of VR-based learning and its long-term effects on student achievement in diverse educational contexts.

The results of this study show that immersive Virtual Reality (VR) has a significant positive impact on science comprehension and engagement among primary school students. The experimental group, which participated in VR-based science lessons, demonstrated a higher improvement in science comprehension compared to the control group. The experimental group's average post-test score increased by 18%, while the control group's score increased by only 8%. Furthermore, the experimental group reported higher levels of engagement, with 82% of students expressing that the VR lessons made science more interesting. This suggests that VR not only helps improve understanding of complex scientific concepts but also fosters increased motivation and participation in the subject matter.

When comparing these results to existing research, the findings align with studies that have highlighted the effectiveness of VR in improving learning outcomes. For example, studies by (Ariya, 2025; Guirand, 2025) have shown that immersive VR environments can enhance learning experiences, particularly in areas that require visualization and interactive engagement. However, this study extends previous research by specifically focusing on primary school students and providing a direct comparison between VR-based learning and traditional teaching methods. The results are consistent with earlier findings but offer new insights into the potential of VR to engage young learners in science education, an area that has been underexplored in previous studies.

These findings reflect the growing importance of using immersive technologies in education. The improvement in science comprehension and engagement observed in the experimental group suggests that VR can bridge the gap between theoretical knowledge and real-world application. Students in the VR group were able to visualize abstract scientific concepts, such as molecular structures and human anatomy, in a way that traditional methods could not offer. This is particularly significant in primary education, where engaging young minds is crucial for fostering long-term interest in subjects like science. The results also highlight that VR may provide a more interactive and immersive learning experience, which is essential for improving comprehension, particularly in subjects with complex content.

The implications of this study are broad, particularly for the integration of technology in primary school science curricula. The positive outcomes observed in the experimental group suggest that VR could be a valuable tool for enhancing science education. By providing a hands-on, visual learning experience, VR can improve students' understanding of abstract concepts, making science more accessible and engaging. This is especially important as traditional teaching methods often struggle to maintain the attention and interest of young learners. The findings also suggest that, given the rapid development of VR technology, integrating it into classroom settings could be a key strategy for improving educational outcomes in science. Schools that are equipped with the necessary resources to implement VR could benefit from a more engaged and knowledgeable student body.

The results of this study can be attributed to the highly interactive nature of VR, which engages multiple senses, and allows students to experience scientific concepts in a more tangible way. By creating a virtual environment where students can interact with scientific phenomena, VR addresses the limitations of traditional methods, where students often passively absorb information from textbooks or lectures. The significant improvement in comprehension and engagement can be explained by VR's ability to stimulate curiosity and provide a more immersive, learner-centered experience. VR provides an environment that not only enhances learning but also motivates students to actively participate, thus making the learning process more dynamic and effective. This explains why the experimental group demonstrated greater improvements compared to the control group, who engaged in less interactive learning experiences.

Looking ahead, further research is needed to explore the long-term effects of VR on science learning and its broader applications in primary education. It would be beneficial to investigate how sustained VR exposure over an extended period impacts knowledge retention

and whether the engagement observed in the experimental group translates into continued interest in science subjects beyond the classroom. Moreover, future studies should explore the scalability of VR implementation, examining whether it can be effectively integrated into diverse educational contexts, particularly in schools with limited resources. Additionally, research should address potential challenges in VR adoption, such as teacher training, technical difficulties, and the need for curriculum adaptations. Overall, these results suggest that VR holds great promise for transforming science education, and further studies could help refine its application to ensure maximum benefit for students.

CONCLUSION

The most important finding of this study is that immersive Virtual Reality (VR) significantly enhances science comprehension and student engagement in primary school settings. The experimental group, which participated in VR-based lessons, showed a greater improvement in science comprehension compared to the control group, with a noticeable increase in motivation and interest in science. This highlights the potential of VR to engage young learners by making abstract scientific concepts more accessible and stimulating their curiosity. The results demonstrate that VR can be a valuable tool for primary education, especially in subjects like science that require visual and interactive learning methods.

This research contributes to the growing body of literature on the use of immersive technologies in education, specifically focusing on VR's impact on younger learners. The study's novel contribution lies in its direct comparison between VR-based learning and traditional methods in the context of science education for primary school students. The mixed-methods approach, combining pre- and post-test data, engagement surveys, and classroom observations, provides a more comprehensive understanding of how VR affects both comprehension and engagement. The findings offer evidence that VR can enhance not only the understanding of scientific concepts but also the overall enthusiasm for learning among primary school students, making it a crucial addition to educational technology discussions.

One limitation of this study is its short duration. The intervention lasted only four weeks, which may not be long enough to fully assess the long-term effects of VR on science comprehension and student engagement. Additionally, the study was limited to two schools, and the sample size, though sufficient for this study, may not fully represent the diverse range of students in primary schools. Future research could benefit from a longitudinal design to assess the long-term impact of VR on learning retention and behavior. Expanding the sample size to include schools from different regions or with different socioeconomic backgrounds would also improve the generalizability of the findings.

Future studies should explore how various factors, such as teacher training, accessibility, and the integration of VR into existing curricula, affect the successful implementation of VR in primary school education. Research could also examine the potential challenges and barriers to adopting VR in schools with limited resources, offering insights into how schools can overcome such obstacles. Additionally, future research could investigate the specific aspects of VR that contribute most significantly to learning outcomes, such as the level of interactivity or the type of content presented, to optimize VR usage in educational settings. This will further our understanding of VR's full potential in enhancing science education and other subject areas in primary schools..

AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; In-vestigation.

Author 3: Data curation; Investigation.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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