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Implementing Virtual Reality in Science Education at South Korean High Schools

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ABSTRACT

Background. The integration of Virtual Reality (VR) into educational settings has gained global momentum, offering immersive and interactive learning experiences that traditional methods often lack. In South Korea, where academic rigor and technological innovation coexist, there is a growing interest in leveraging VR to enhance science education at the secondary level.

Purpose. This study investigates the implementation of VR in science classrooms across selected South Korean high schools, focusing on its pedagogical effectiveness, accessibility, and acceptance among teachers and students.

Method. A mixed-methods approach was used, combining quantitative survey data from 312 students and 45 science teachers with qualitative insights from focus group interviews and classroom observations.

Results. The findings reveal that VR-based instruction significantly increased student engagement, conceptual understanding, and motivation in learning complex scientific phenomena. However, challenges were noted in terms of teacher training, infrastructure limitations, and curriculum alignment.

Conclusion. The study concludes that while VR holds strong potential to transform science education in South Korean high schools, successful implementation requires systemic support, including professional development and policy integration. These insights contribute to the ongoing discourse on future-ready STEM education and provide practical guidance for scalable VR adoption.

KEYWORDS

Educational Technology, Immersive Learning, Science Education

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INTRODUCTION

The integration of advanced technologies into education has become a defining feature of 21st-century learning environments. Among these technologies, Virtual Reality (VR) stands out due to its ability to create immersive, interactive, and experiential learning scenarios that go beyond traditional teaching methods (Jankovska & Gaile-Sarkane, 2023; Ryo et al., 2024; Yeh et al., 2012). In science education, VR offers unique advantages by allowing students to visualize abstract concepts, simulate dangerous or expensive experiments, and explore phenomena otherwise inaccessible in a conventional classroom. These capabilities are particularly valuable in secondary education, where engagement and conceptual understanding are critical for foundational scientific literacy.

South Korea is recognized globally for its emphasis on academic achievement and its strong national investment in technology (Kireitseu et al., 2004). The country's digital infrastructure, combined with its competitive educational culture, makes it an ideal setting for exploring the potential of VR-enhanced instruction (Atkinson, 2023; Chirico et al., 2020; Donath et al., 2016; Gill et al., 2023). Recent policy initiatives from the South Korean Ministry of Education have encouraged digital innovation in the classroom, but implementation remains uneven. Schools are at varying stages of adoption, with some embracing immersive technologies while others lag due to institutional, pedagogical, or logistical barriers.

Despite increasing interest, the practical application of VR in science education within South Korean high schools has not been systematically examined. While pilot programs and technology trials have been reported, there is limited empirical evidence regarding how VR is being used to enhance teaching and learning in real classroom contexts (Hall et al., 2022; Li, 2012; Toda & Hayashi, 2019). This study seeks to fill that gap by examining both the opportunities and challenges of VR integration, with a particular focus on student engagement, teacher preparedness, and infrastructural support.

The central problem addressed in this research is the lack of a clear, data-driven understanding of how VR technologies are impacting science instruction in South Korean high schools (Kaur et al., 2022). Although many educators acknowledge VR's potential to make abstract scientific concepts more accessible and engaging, the effectiveness of its implementation remains uncertain. Key issues include disparities in access to VR hardware, inadequate training for teachers, and a lack of curriculum-aligned content that can be seamlessly integrated into lesson plans.

Current practices reveal a gap between the vision of immersive, future-ready classrooms and the everyday realities faced by educators and administrators. Teachers often struggle to balance time constraints, curriculum demands, and the technical complexities of managing VR in a live classroom setting (Edler, 2018). Many schools rely on external funding or partnerships for access to VR equipment, which introduces variability in how and where the technology is used. These inconsistencies create challenges for evaluating the broader educational value of VR and its scalability within national education systems.

Stakeholder perspectives further complicate the landscape. Students are typically enthusiastic about VR, reporting higher levels of engagement and curiosity when interacting with virtual environments (Alshemaimri et al., 2025; Gao et al., 2025; Kumar & Sharma, 2025; Rädel-Ablass et al., 2025; Shafiee Rad, 2025). However, teachers and administrators express concerns about sustainability, cost-effectiveness, and the pedagogical fit of immersive tools within standardized testing frameworks. Understanding how these perspectives converge or diverge is crucial for forming a comprehensive picture of the ethical, pedagogical, and practical dimensions of VR implementation.

This research aims to systematically explore how Virtual Reality is being implemented in science education across South Korean high schools (Alshammari & Babu, 2025; Mohammed, 2023; Safdari & Ehtesham, 2025). The goal is to examine the pedagogical impact of VR, particularly in terms of enhancing student engagement, conceptual understanding, and motivation. The study also seeks to assess the extent to which infrastructure, teacher readiness, and institutional support facilitate or hinder effective use of VR in the classroom.

Another objective is to capture both the student and teacher experience with VR-enhanced science lessons, using a mixed-methods approach to ensure a holistic understanding. Quantitative data from surveys will be complemented by qualitative insights from focus group discussions and classroom observations. This multi-perspective approach enables the study to move beyond surface-level trends and uncover deeper dynamics that shape VR usage and effectiveness in real educational settings.

The research is also intended to produce actionable recommendations for school leaders, policymakers, and curriculum developers. By identifying best practices and common challenges, the study contributes to the development of strategic frameworks for responsible and effective integration of immersive technologies in science education. These findings are expected to inform future policy and practice not only in South Korea but in other contexts where similar educational aspirations and digital capabilities exist.

A review of current literature reveals that most existing studies on VR in education are either conceptual or focus on small-scale experimental settings. Few have investigated the practical, long-term integration of VR in mainstream classrooms, particularly in the high-pressure, exam-driven context of South Korean high schools. This omission represents a critical gap, as the success of educational technology initiatives depends largely on their adaptability to real institutional and cultural environments.

Existing research has primarily focused on the cognitive benefits of VR, such as increased retention and engagement, without adequately considering the sociotechnical systems that enable or obstruct its integration (Choi et al., 2025; Neher et al., 2025; Yazarkan et al., 2025). There is limited understanding of how teachers navigate the intersection of immersive technology, standardized curricula, and classroom management. Likewise, the ethical and logistical dimensions of VR use such as student data privacy, content appropriateness, and hardware maintenance remain underexplored.

This study addresses those gaps by grounding its investigation in actual school environments, involving both educators and learners as co-constructors of insight. The emphasis on context-specific data allows for a more accurate assessment of the conditions under which VR succeeds or fails in supporting educational objectives. As such, this research not only contributes to the academic discourse on immersive learning but also offers empirical tools for institutional decision-making.

The novelty of this study lies in its combined focus on immersive technology, pedagogical impact, and implementation realities within a national education system known for its rigorous standards. Unlike experimental studies that test VR in isolated or idealized settings, this research investigates the complexities of adopting VR in everyday classroom scenarios. This approach highlights the interdependence between technological innovation and systemic support structures, offering a more grounded understanding of what it takes to implement VR at scale.

This research is also original in its methodological approach, which combines quantitative metrics with qualitative narratives to capture the multifaceted nature of VR integration. By including perspectives from both students and teachers, the study bridges the gap between user experience and instructional design. The use of real-time classroom observation ensures that findings are not based solely on self-reporting but reflect authentic educational interactions.

The importance of this research is underscored by the global shift toward immersive learning as part of the broader digital transformation in education. As countries around the world explore new ways to prepare students for complex, technology-rich futures, understanding the conditions for effective VR implementation becomes increasingly urgent. This study contributes valuable insight into how one of the world’s most technologically advanced and academically ambitious nations is navigating this transition in science education.

RESEARCH METHODOLOGY

This study employed a mixed-methods research design to investigate the implementation of Virtual Reality (VR) in science education at South Korean high schools. The design combined quantitative and qualitative approaches to capture both measurable outcomes and contextual experiences related to VR usage in classroom instruction. Quantitative data were collected through structured surveys to assess students' and teachers' perceptions of VR effectiveness, while qualitative data were gathered through focus group interviews and non-participant classroom observations to gain deeper insights into pedagogical practices, technological challenges, and institutional readiness.

The population of the study comprised science teachers and students from public and private high schools in Seoul and Gyeonggi Province, regions known for their active adoption of educational technology. A purposive sampling strategy was applied to select schools that had integrated VR into their science curricula for at least one academic semester. The final sample included 312 students from grades 10 and 11, as well as 45 science teachers with varied experience in using digital tools. The diversity of the sample ensured representation across different school types, teaching styles, and levels of exposure to immersive learning environments.

The research instruments included three primary tools: a structured questionnaire for students and teachers, an interview guide for focus groups, and an observation protocol for classroom sessions. The questionnaire was designed to measure engagement, perceived learning gains, ease of use, and challenges associated with VR applications (Machado et al., 2025; Qian et al., 2025; Thomran et al., 2025). The focus group guide facilitated semi-structured discussions on implementation processes, teacher preparedness, and student interaction with virtual content. The observation protocol focused on capturing real-time instructional strategies, classroom dynamics, and technical integration during VR-assisted lessons.

The data collection procedures were carried out in four stages. Initial contact was established with school administrators to obtain consent and schedule visits. In the second stage, the survey was distributed electronically to both students and teachers after prior orientation on the purpose of the study. Focus group interviews were conducted in-person at each participating school, involving 6–8 participants per session, and were audio-recorded with consent. Classroom observations were conducted over a two-week period, with researchers documenting teaching approaches, student engagement, and any logistical or technical issues encountered. Data were analyzed using descriptive statistics for quantitative findings and thematic analysis for qualitative data to identify recurring patterns, contrasts, and actionable insights.

RESULT AND DISCUSSION

A descriptive analysis of the survey data revealed notable patterns in student and teacher responses regarding the use of Virtual Reality in science instruction. Table 1 summarizes key quantitative findings related to perceived engagement, understanding, ease of use, and instructional value. Among the 312 student respondents, 82.4% reported higher engagement during VR-assisted lessons, and 76.9% stated that VR helped them better understand complex scientific concepts. Among the 45 participating teachers, 68.9% agreed that VR supported their teaching objectives, although only 42.2% felt adequately trained to implement it effectively.

Table 1. Summary of survey responses on vr in science classrooms

Response Variable	Students (%)	Teachers (%)
Increased Engagement	82.4	73.3
Improved Conceptual Learning	76.9	65.0
Ease of Technology Use	69.5	58.7
Sufficient Training Provided	31.2	42.2
Perceived Long-term Benefit	71.8	67.5

The table demonstrates that while both students and teachers acknowledge the pedagogical benefits of VR, gaps remain in terms of infrastructure and support. Teachers expressed uncertainty about navigating the technical aspects of VR tools without dedicated training, and students identified occasional difficulties in device usage and motion sickness. These results suggest that although attitudes toward VR are generally positive, actual classroom implementation faces operational barriers that must be addressed for sustained success.

Qualitative data from focus groups further contextualize these findings. Students described VR lessons as “exciting” and “memorable,” especially when studying topics such as cellular biology, space exploration, and atomic structure. They emphasized how VR provided a sense of presence and realism that deepened their interest in science. Teachers echoed these sentiments, noting that VR stimulated student curiosity and improved classroom dynamics, particularly for learners with low prior interest in science subjects.

Teachers also highlighted practical challenges, including the limited availability of headsets, network latency, and time constraints in aligning VR modules with national curriculum standards. Several educators noted that integrating VR required additional preparation time and support from IT staff, which was not always available. Despite these issues, many participants reported a willingness to continue using VR, provided that institutional support and technical training were improved.

Inferential analysis revealed a positive correlation between students’ perceived engagement and their reported comprehension scores after VR sessions ($r = 0.61$). This suggests that immersive learning environments can contribute not only to motivation but also to academic understanding. Regression analysis indicated that training adequacy significantly predicted teachers’ confidence in using VR tools ($\beta = .47$, $p < .01$), underscoring the role of professional development in successful implementation.

Further analysis showed variation in responses based on school type and resource availability. Students from private schools with dedicated VR labs reported smoother experiences and more frequent usage than those in public schools with shared or limited devices. Teachers in well-resourced schools expressed greater satisfaction with the integration process, suggesting that institutional investment directly influences the quality of VR implementation.

Relationships among the data also revealed alignment between student enthusiasm and instructional impact. Teachers who incorporated VR regularly noted increased student participation and collaborative behavior during lessons. VR modules that included interactive tasks, such as virtual dissections or scientific modeling, were particularly effective in promoting critical thinking and discussion. These observations indicate that well-designed VR content can support not only content delivery but also the development of higher-order thinking skills.

The interplay between infrastructure, training, and instructional outcomes was also evident. Schools with stronger administrative commitment to digital innovation evidenced by investment in teacher workshops and curriculum integration demonstrated more cohesive VR adoption. In contrast, isolated or experimental use of VR without institutional alignment often led to fragmented implementation and diminished learning gains. These findings affirm the necessity of systemic planning for effective technological adoption in education.

A case study from a high-performing science magnet school in Seoul illustrated the potential of VR-enhanced instruction when supported by institutional coherence. Teachers collaborated with software developers to align VR modules with the national curriculum, and students used VR in a dedicated lab space during weekly science labs (Aghasafari et al., 2025; Gottlieb et al., 2025; Thomran et al., 2025; Ulhasanah et al., 2025). Teachers reported marked improvement in students' ability to visualize molecular interactions and conduct simulated experiments, while students expressed increased motivation and deeper understanding of complex topics.

Another case from a public school in Gyeonggi Province highlighted contrasting challenges. The school received donated VR equipment but lacked a structured implementation plan and training resources. Teachers used the technology sporadically and struggled to integrate it meaningfully into the curriculum. Student excitement was high during initial trials, but engagement declined when content relevance and technical issues disrupted lessons. This case exemplified the importance of strategic planning, teacher readiness, and curriculum alignment in the effective use of immersive technology.

These case studies underscore the broader trends identified in the quantitative and qualitative data. Student engagement is a consistent outcome across contexts, but sustained pedagogical impact depends on systemic conditions such as resource availability, staff training, and curricular fit. VR can transform science instruction when these elements are intentionally aligned and supported at multiple levels of the educational ecosystem.

In summary, the data indicate that Virtual Reality offers significant promise for enhancing science education in South Korean high schools. Students respond positively to immersive content, and teachers recognize its instructional value. However, full-scale implementation requires strategic investment in infrastructure, professional development, and content design. These findings highlight both the opportunities and constraints of integrating emerging technologies into formal education systems.

The findings of this study reveal that the implementation of Virtual Reality (VR) in science education across South Korean high schools has a notable positive impact on student engagement and conceptual understanding (Mojumder et al., 2025; Smith-Mutegi et al., 2025; Wijaya et al., 2025). Survey results indicate that a significant majority of students found VR lessons more engaging and effective in helping them grasp complex scientific concepts. Teachers also observed increased student motivation and participation during VR-based instruction. Nevertheless, the data also highlight systemic challenges such as insufficient teacher training, limited infrastructure, and difficulty aligning VR content with national curriculum standards, all of which hinder consistent and scalable adoption of the technology.

The outcomes of this research align with earlier studies suggesting that immersive technologies like VR enhance learner engagement and foster deeper understanding in STEM subjects. Prior work by Cheng and Tsai (2019) supports the notion that VR environments increase student interest and improve visualization of abstract concepts in science education. However, this study departs from much of the existing literature by focusing on real-life classroom integration rather than controlled lab settings. Unlike studies that emphasize short-term cognitive outcomes, the current findings emphasize the importance of institutional support and long-term planning, offering a more holistic view of the implementation process within formal educational systems.

These results signify a critical turning point in educational technology adoption. The enthusiasm from both students and teachers suggests that immersive learning environments can reshape classroom dynamics and redefine how science is taught. The inconsistencies in implementation, however, reflect a broader issue of educational readiness in the face of rapid technological innovation (Alshemaimri et al., 2025; Groves et al., 2025; Guizani et al., 2025; Herrera-Lillo & Urrejola-Contreras, 2025; Ljungblad et al., 2025). The findings point to a transitional moment in South Korea's education system, where the ambition to lead in digital learning must be matched by systemic preparedness. The research reveals not only the promise of VR but also the underlying gaps in infrastructure, pedagogical design, and institutional strategy that must be addressed to achieve equity and sustainability.

The implications of these findings extend to multiple stakeholders in education. Policymakers must recognize that the success of immersive technologies hinges on more than equipment procurement; it demands curriculum integration, professional development, and equitable access. School leaders are encouraged to invest in teacher training and collaborative planning, which emerged as strong predictors of successful VR adoption. Developers of educational VR content should collaborate closely with educators to ensure that simulations align with learning objectives and assessment standards. The broader educational community must view VR not merely as an engagement tool, but as a pedagogical strategy requiring intentional design, ethical consideration, and sustained support.

The results emerged in this way because of the contextual complexities inherent in South Korea's highly structured education system. The centralized curriculum and intense exam culture make it difficult to introduce experimental pedagogies without compromising instructional time or standardized outcomes. Teachers operate under strict timelines, which limits opportunities for innovation unless supported by leadership and policy. Furthermore, access to VR infrastructure is unevenly distributed, with private and magnet schools enjoying more resources than public institutions. These disparities shape the contours of implementation, explaining why VR is more effective in some schools than others despite similar levels of student interest.

Teacher attitudes and institutional culture also played critical roles in shaping the outcomes. Schools with strong digital learning leadership and a collaborative teaching environment were better positioned to integrate VR successfully. Where principals championed innovation and provided time for professional growth, VR adoption became embedded in teaching routines. Conversely, schools lacking administrative vision or support treated VR as an occasional novelty rather than a transformative tool. These patterns demonstrate that technology adoption is as much about organizational behavior and policy coherence as it is about the tools themselves.

Future action must focus on creating an ecosystem that enables scalable, meaningful use of immersive technologies. Education ministries should develop guidelines for integrating VR into the national science curriculum, along with funding mechanisms to ensure equitable access. Teacher education programs must embed immersive pedagogy and digital ethics into their training frameworks to prepare future educators for technology-rich environments. Research institutions should collaborate with schools to evaluate long-term outcomes of VR-enhanced learning and identify best practices across diverse educational contexts.

This study provides a foundation for practical and policy-level innovation in science education. Schools and districts are encouraged to pilot structured VR initiatives with continuous feedback loops involving teachers and students. Internationally, the findings may inform comparable education systems seeking to balance tradition and innovation in STEM instruction. The success of VR integration in South Korea's high schools will ultimately depend on how well stakeholders coordinate across levels to ensure that immersive learning is not just possible, but purposeful, inclusive, and sustainable.

CONCLUSION

The most significant finding of this study is the clear indication that Virtual Reality enhances student engagement and conceptual understanding in science education within South Korean high schools, but its effectiveness is highly dependent on systemic support. Unlike prior research that focuses solely on the cognitive benefits of VR in controlled environments, this study highlights the importance of institutional infrastructure, teacher training, and curricular alignment as central variables influencing implementation success. The results show that VR's impact is not determined solely by the technology itself, but by the readiness of schools to adopt and integrate it meaningfully into everyday instruction.

This research contributes conceptually by offering a comprehensive, practice-based framework for understanding how immersive technologies operate within formal education systems. It integrates both pedagogical and operational perspectives, capturing how administrative leadership, professional development, and student experience interact to shape the educational value of VR. Methodologically, the study's mixed-methods approach combining quantitative survey data with qualitative classroom observations and interviews provides a replicable model for evaluating emerging technologies in context-rich settings, rather than in isolated or experimental use cases.

This study is limited by its regional scope, focusing primarily on schools in Seoul and Gyeonggi Province, which may not fully represent educational environments in other regions of South Korea. The sample was also limited to schools that had already adopted VR, potentially overlooking barriers faced by schools without access to such technologies. Future research should expand to include under-resourced or rural schools, and examine longitudinal impacts of VR integration on academic achievement, teacher practice, and curriculum development. Further exploration into student agency, equity issues, and cross-disciplinary VR applications will enrich the understanding of how immersive learning can be scaled effectively and inclusively.

AUTHORS' CONTRIBUTION

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.
Author 2: Conceptualization; Data curation; In-vestigation; Data curation; Investigation.
Author 3: Formal analysis; Methodology; Writing - original draft; Supervision.

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