

PRIMARY SCHOOL STUDENTS' PERCEPTIONS OF IMMERSIVE  
VIRTUAL REALITY -BASED SCIENCE LEARNING TO  
ENHANCE AFFECTIVE LEARNING OUTCOMES

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**Abstract:** Immersive Virtual Reality (IVR) is becoming a key tool in elementary science education, especially in enhancing students' emotional engagement, virtual presence and classroom interaction. In this study, we explored students' authentic learning experiences in an IVR science classroom through focus group interviews. We analyzed the effects of immersion, interactivity, and task difficulty on motivation and affective learning outcomes. The findings reveal that although IVR provides a highly immersive learning environment, its operational complexity and technological distractions may also negatively affect students' emotions, thereby interfering with their learning engagement. Therefore, the study suggests that future IVR courses should balance immersion and operability to ensure that students maximize the benefits of the experience and learning outcomes. Finally, this paper also suggests improvements in the practical application of VR teaching. It suggests that in the future, combining physiological indicators with long-term tracking studies can expand the boundaries of IVR applications in basic education.

**Keywords:** Immersive Virtual Reality (IVR), elementary science education, virtual presence, interactive experience, emotional engagement, collaborative learning.

## INTRODUCTION

With the continuous innovation of educational technology, Immersive Virtual Reality (IVR) has garnered significant attention in the field of education in recent years, particularly for its potential to enhance students' learning motivation, engagement, and emotional investment (Makransky & Lilleholt, 2018; Radianti et al., 2020). IVR offers learners an unprecedented learning experience through its high immersion, interactivity, and realism, particularly suited for subjects like natural sciences, which require spatial construction and dynamic demonstrations. However, current research has primarily focused on higher education, with limited exploration of primary school students' experiences and emotional factors in IVR environments (Jensen & Konradson, 2018). While existing studies suggest that IVR can enhance learning motivation, there remains debate over whether immersion promotes learning among younger learners. Therefore, understanding the impact of virtual presence, natural experience, and emotional responses on IVR's emotional engagement and learning outcomes is particularly critical for optimising practices in primary education.

This study focuses on fifth-grade students, aiming to explore their immersive experiences and learning perceptions in IVR science classrooms from the students' perspective and to analyse the key factors influencing learning motivation and emotional learning outcomes. The study investigates how virtual presence, natural experience, emotional responses, and task-related factors influence emotional engagement and learning outcomes in providing theoretical support and practical guidance for effectively applying immersive learning technologies in primary science education.

The primary purpose of this study is to answer the following research question:

- How do students' experiences in immersive VR learning environments affect affective learning outcomes through emotional engagement?

## LITERATURE REVIEW

This study adopts the CAMIL theory (Cognitive Affective Model of Immersive Learning) proposed by Makransky and Lilleholt (2018) as its theoretical foundation to explain the relationship between virtual presence, emotional responses, and learning outcomes in immersive VR learning. In recent years, IVR technology has been increasingly applied in education. Research indicates that IVR can effectively enhance students' learning motivation and engagement (Makransky & Lilleholt, 2018; Radianti et al., 2020). Especially in science education, IVR provides a highly immersive, visual, and interactive learning environment, making abstract scientific concepts more intuitive and manipulable (Jensen & Konradsen, 2018). Unlike traditional teaching methods, immersive learning environments can significantly enhance students' learning interests and emotional experiences (Parong & Mayer, 2021). Additionally, research has emphasized that when designing IVR teaching activities, it is essential focus on the balance between the contextual authenticity of learning tasks, learners' cognitive load, and emotional engagement (Makransky et al., 2019) to achieve optimal teaching outcomes. While existing research has explored the educational potential of IVR from a cognitive perspective, the relationship between primary school students' emotional experiences, virtual presence, and affective learning outcomes in IVR remains an area requiring further in-depth investigation.

## METHODOLOGY

This study used a qualitative research methodology to complement a sequential interpretive mixed-methods research study. The researcher selected thirteen fifth-grade primary school students as participants through simple random sampling and conducted a one-session focus group interview after science class to gain insight into the students' perceptions of IVR as applied to science learning. The interviews were collated and analysed using the thematic analysis method proposed by Braun and Clarke (2006). All students interviewed are represented in the data presentation by an anonymised number (e.g., Student 1, 2, 3), with different numbers representing students who expressed their views in the interviews. Emerging themes that naturally surfaced during the interviews were also attended to during the research process and incorporated into the analytical framework to provide a more comprehensive picture of students' learning experiences.

## FINDINGS

This study conducted a thematic analysis of interview data from fifth-grade students to identify six core experiential themes in their IVR science learning: Virtual Presence, Natural Experience, Task Complexity & Performance, Emotional Responses, Emotional Engagement Level, and Immersion & Learning Outcomes.

### *Virtual Presence*

Students generally feel that they are immersed in the IVR environment, experiencing sensations such as 'being in space' and 'floating in the universe,' which significantly enhances their focus and interest in learning. They also note that collaborating with peers on tasks in the virtual environment provides a genuine interactive experience.

I feel like I'm floating in space, surrounded by planets, as if I were really an astronaut (Student 1).

We completed tasks together in VR, like teaming up for an adventure, which was really fun (Student 2).

### *Natural Experience*

Most students reported that the operational feedback in the IVR environment felt very realistic, with 'moving the remote control causing the planets to move accordingly,' providing them with an unprecedented sense of natural control and immersion. This natural interaction enhances the intuitiveness and immersion of the learning experience. However, some students also noted that image stuttering or device latency occasionally caused dizziness, affecting the quality of the experience. Overall, the naturalness of control and visual smoothness have a significant impact on students' immersive experience.

### *Task Complexity & Performance*

Students had mixed feedback on the difficulty of different tasks. Simple tasks (such as identifying planets) provided positive experiences and a sense of accomplishment, while complex tasks (such as adjusting orbits)

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presented challenges and even frustration. This proves that task design should strike a reasonable balance between fun and difficulty.

I finished the task of finding Earth quickly and felt very proud of myself (Student 5).

I tried several times but couldn't adjust the orbit properly, which was a bit frustrating (Student 6).

### *Emotional Responses*

Students showcased numerous positive emotions in VR learning, such as happiness, excitement, and curiosity, which helped boost their motivation to learn. However, a few students also experienced negative emotions such as dizziness and anxiety, indicating that individual differences should be taken into account in the design.

I'm really looking forward to the VR class. It feels like an adventure every time (Student 7).

When I keep rotating the screen, I feel a little dizzy (Student 8).

### *Emotional Engagement Level*

Student interviews revealed that emotional engagement is crucial in promoting understanding and long-term memory in IVR learning. Students are willing to actively participate and enjoy exploring new knowledge, and emotional engagement significantly enhances their motivation to learn.

I can remember the position of each planet because I placed them there myself (Student 9).

I like science now because VR classes are fun (Student 10).

### *Immersion & Learning Outcomes*

Most students believe that immersive experiences help them better understand scientific knowledge and enhance their sense of satisfaction and accomplishment in learning. Immersion not only improves learning efficiency but also stimulates long-term interest in learning.

I feel that VR learning really helps me understand the solar system, much more clearly than regular textbooks (Student 11).

After finishing the course, I still remember the order of the planets (Student 12).

Appendix A lists the interview outline to further clarify the correspondence between the interview content and the analysis structure. Appendix B1 shows the theme coding table, which clarifies the pairing relationship between the research questions, main themes, and keywords. Appendix B2 showcased the structural theme network behind the interview data from multiple dimensions through word frequency statistics, theme frequency, and co-occurrence analysis.

## **CONCLUSION**

The findings of this study provide new insights for teachers in designing and implementing IVR in primary science education. Students demonstrated high levels of virtual presence, emotional responses, and interactive engagement in IVR classrooms, with these factors collectively promoting their understanding of scientific concepts, enhancing their learning motivation, and improving their overall learning satisfaction. The study found that intuitive methods and realistic simulation experiences effectively stimulated students' learning interest but also revealed that issues such as system lag and overly complex tasks could negatively impact emotional engagement and learning outcomes.

Therefore, it is recommended that teachers strike a balance between immersion and operability when designing IVR teaching content in ensuring that students can complete learning tasks smoothly while maintaining emotional engagement. Teaching designs that combine cooperative learning with emotional arousal can help enhance

learning depth and meaning. Research indicates that emotional engagement plays a key mediating role between virtual presence and affective learning outcomes.

The findings of this study align with the CAMIL model, validating the mediating mechanism between immersion and emotional engagement in learning motivation and affective learning outcomes. When promoting IVR teaching in primary education, it is essential to continue prioritising student-centred design principles, account for task difficulty variations, and integrate emotional guidance strategies to facilitate students' comprehensive development and deep learning in immersive learning environments. This study provides new insights into immersive teaching in primary science education, emphasising the potential of VR technology to enhance learning interest, emotional engagement, and classroom interaction. Future research could combine affective computing and physiological feedback technologies to reveal further changes in students' emotional fluctuations and learning outcomes during long-term IVR learning.

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## APPENDIX

**Appendix A: Interview Outline****1. Virtual Presence and Interaction**

When using Virtual Reality for learning, did you feel as if you were actually standing on the surface of the moon? How did you experience discussing with other students in this virtual environment? Can you share specific feelings and experiences? How did this affect your learning?

**2. Natural Experience**

In the VR environment, did you feel that your actions and experiences were as natural as in the real world? Did this feeling enhance your interaction with classmates while completing tasks? If you had a different feeling, what was it like? How did it impact your learning experience?

**3. Task Complexity & Performance**

When completing tasks in VR (e.g., manipulating virtual hands), did you find it easy to learn and operate these tasks? Did you feel a sense of accomplishment? If the tasks became more complex, how would you respond?

**4. Emotional Reactions**

During the learning process, how did your emotional reactions unfold? Were there particular moments that made you feel excited or frustrated? How did these emotions impact your engagement and attitude toward learning?

**5. Degree of Emotional Engagement**

In VR learning, did you feel that your emotional engagement differed from real-world learning? What specific impact did this different emotional engagement have on your learning outcomes? Please share some examples.

**6. Immersion and Learning Outcomes**

How much do you think the sense of immersion in the VR environment impacted your learning outcomes? Can you share specific examples? Overall, how do you evaluate the entire VR learning experience? Do you have any suggestions for improving this learning method?

Appendix B1: Subject Coding Table

Table 1. Subject Coding Table

Research Questions	Primary theme and sub themes	Keywords
How do student experiences in immersive VR learning environments affect affective learning outcomes through emotional engagement?	<b>Virtual Presence</b>	<i>1. Feeling like I'm in... / I feel like I'm in... / It's like floating in... / I'm really in... / It's like floating.</i>
	- Physical Presence	
	- Social Presence	<i>2. Seeing classmates / Communicating / Interacting / They run fast / Teaming up / Discussing</i>
	- Interactive Experience	
	- Immersion	<i>3. I use the controller / It responds when I click / I can touch it / Interact / Touch / Drag</i>
	<b>Task Complexity &amp; Performance</b>	
	- Ease of Use	<i>1. Simple / Complex / Easy / Difficult to operate</i>
	- Task Achievement	<i>2. Completed / Passed / Task successful / Very rewarding</i>
	- Reaction to Complex Tasks	
	- Technical Challenges	
	<b>Emotional Responses</b>	
	- Positive Emotions	<i>1. Happy / Excited / Like / Great / Interesting</i>
	- Negative Emotions	
	- Impact on Learning	<i>2. Dizzy / Uncomfortable / Lost / Bored / Afraid</i>

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**Emotional Engagement Level**

- Positive Emotional Engagement Enhances Learning *1. It's more interesting here / It's more exciting here*
- Negative Emotional Engagement Hinders Learning
- Emotional State Impacts Learning Outcomes

**Immersion & Learning Outcomes** *1. Remembered more / Learned a lot*

- Impact of Immersion on Learning
- Learning Perception & Satisfaction

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**Appendix B2: Theme Frequency and Relationship Analysis**

The core content results of this study's thematic analysis have generated six core themes, each containing sub-themes.

**1. Theme Frequency**

In the tables generated by NVivo 14, each theme is followed by a 'Reference Count,' which indicates the number of times that theme appears in the data. For example, 'Emotional Responses' appears 15 times, and 'Immersion & Learning Outcomes' appears 4 times.

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'Emotional Responses' were frequently mentioned in the interviews, indicating that the interviewees were concerned about emotional changes in VR learning. This may suggest the critical role of immersion and emotional engagement in learning.

**Table 2. Reference Points**

Name	Document	Reference Count
<b>1. Virtual Presence</b>	1	10
Social Presence	1	3
Physical Presence	1	6
Self Presence	1	1
<b>2. Natural Experience</b>	1	3
Collaboration with Peers	1	1
Realism in Learning	1	1
Control Naturalness	1	1
<b>3. Task Complexity &amp; Performance</b>	1	8
Task Achievement	1	1
Reaction to Complex Tasks	1	2
Technical Challenges	1	2
Ease of Use	1	3
<b>4. Emotional Responses</b>	1	15
Impact on Learning	1	6
Negative Emotions	1	2
Positive Emotions	1	7
<b>5. Emotional Engagement Level</b>	1	10
Emotional State Impacts Learning Outcomes	1	1
Negative Emotional Engagement Hinders Learning	1	7
Positive Emotional Engagement Enhances Learning	1	2
<b>6. Immersion &amp; Learning Outcomes</b>	1	4
Learning Perception & Satisfaction	1	2
Impact of Immersion on Learning	1	2

## 2. Theme Relationship Analysis

In further data analysis, the study focuses on the frequency of individual themes and examines the cross-relationships and logical connections between different themes. Through NVivo's co-occurrence analysis, it is possible to observe which themes frequently co-occur in the exact interview text, thereby revealing the multidimensional psychological states and behavioural pathways experienced by students in Immersive Virtual Reality (IVR) learning. For example, 'immersion' often co-occurs with 'learning outcomes,' suggesting that highly immersive experiences may promote more profound understanding and satisfaction among students; 'task complexity and performance' also exhibits high co-occurrence with 'emotional responses,'

implying that higher task challenges may trigger significant emotional reactions among students.

Figure 1 illustrates the hierarchical structure between this study's main themes and subthemes. Through a systematic coding process, researchers categorised students' interview content into six core themes, each further divided into several subthemes, reflecting students' multi-layered experiences in VR learning. For example, 'Virtual Presence' includes dimensions such as 'Physical Presence' and 'Social Presence,' reflecting changes in students' perceptions of themselves, others, and the environment. This hierarchical structure diagram lays the theoretical foundation for subsequent theme clustering and cross-analysis.

**Figure 1. Thematic Code Hierarchy Diagram**

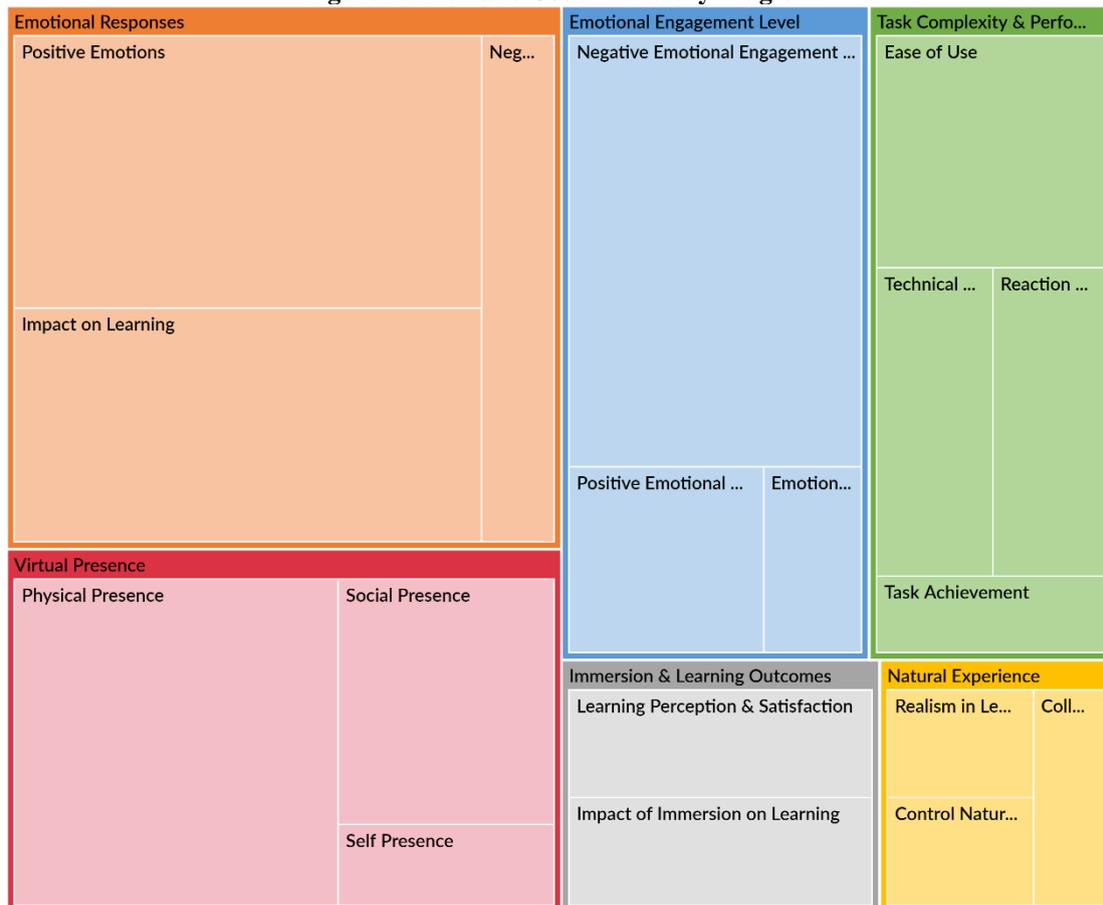


Figure 2 used word frequency analysis to generate a word cloud to visually present the keywords most frequently used by students during the interviews. As shown in the figure, terms such as 'learning,' 'feeling,' 'still,' 'not,' 'play,' and 'planet' were frequently mentioned, indicating that students were particularly impressed by the immersive experience, hands-on interaction, and emotional changes in IVR learning. Additionally, specific terms such as 'movement,' 'virtual,' and 'see' also indicate students' high level of attention to interaction design and visual content. The word cloud provides intuitive evidence for understanding students' areas of focus and perceptual pathways.

Figure 2. Word Cloud of Frequently Mentioned Words in Students' IVR Science Learning Reflections

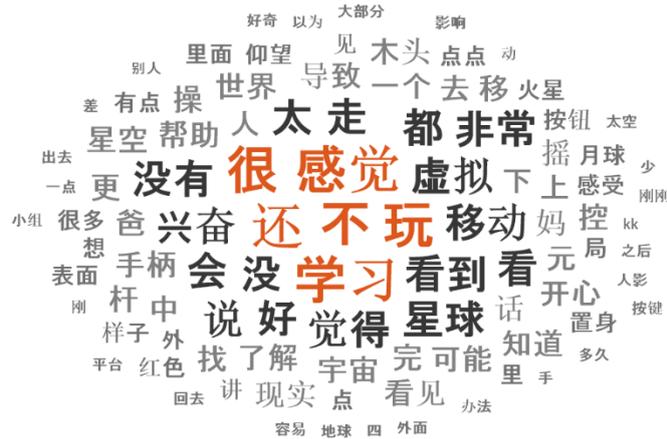


Figure 3 illustrates the natural clustering structure formed by different themes during the coding process, revealing their co-occurrence relationships and psychological connections. Through NVivo's code cluster analysis, it can be seen that themes such as 'emotional experience,' 'emotional engagement,' 'immersion,' and 'learning outcomes' have formed relatively concentrated clusters, indicating that they are frequently mentioned together in the data and may constitute key mechanisms of the VR learning experience. This relationship diagram visually presents the underlying structural network within the interview content, aiding in further constructing the explanatory model for this study.

Figure 3. Thematic Code Cluster Analysis Diagram

