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Immersive Virtual Reality as an Authentic Learning Activity in Problem Based Learning: A Case Study of Elementary Students' Learning Behaviors

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Abstract. Problem-based learning (PBL) has become increasingly popular in K-12 education. It has also presented educators and designers with the challenge of providing authentic resources to students. One possible solution is the use of immersive virtual reality (IVR) as an authentic resource. This case study sought to elicit the perspectives and observed learning behaviors of elementary students using IVR in their PBL-based STEM class. The emergent themes suggested elementary students view IVR as a valuable authentic resource. Observed learning behaviors indicated elementary students can make observations and draw conclusions from IVR content.

Keywords: hypothetical model of immersive cognition, ICAP framework, immersive virtual reality, problem-based learning, student collaboration

1 Introduction

Originating from medical schools, Problem-Based Learning (PBL) has expanded to K-12 students. A key element of PBL is the authenticity of the problem itself, which is needed in order to provide positive learning experiences to the students (Scott, 2014). This authenticity of task continues to be a struggle in PBL designs (Savin-Baden, 2016). One possible solution is to incorporate immersive virtual reality (IVR) into the PBL cycle. IVR is a mobile device-generated scene that simulates the real world through the use of 3D 360˚ visual stimuli and Head Mounted Displays (HMDs) to fully immerse the user in the virtual environment (Xie, 2010). To date, research on IVR in instruction has been limited to memory recall (Bailey et al., 2012; Rupp et al, 2016) and possible abstract learning activities and experiences (Ahn et al., 2016; Passig et al., 2007) with collegiate aged students. IVR could potentially be utilized as an authentic PBL learning context to make a problem scenario more realistic.

The purpose of this descriptive case study was to understand elementary students' views and perceptions of IVR's impact on their engagement with and describe their learning behaviors in a collaborative PBL-based STEM class. This study addressed the following research questions:

RQ1: What are elementary students' perceptions of using IVR in their PBL-based STEM class on their engagement with the content?

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RQ2: What characterizes students' cognitive and collaborative behaviors when using IVR in their PBL-based STEM class, including:
RQ2a: Learner-to-content interactions
RQ2b: Learner-to-learner interactions
RQ2c: Types of questions students are asking
RQ2d: Types of observations students are making
RQ2e: Other observed learning behaviors

2 Theoretical Framework and Literature

2.1 Problem-Based Learning

The use of authentic problems in PBL positively impacts and deepens the learning experience for students, leading to higher levels of engagement (Scott, 2014). When problems are directly connected to real-life situations, students are more likely to feel a sense of ownership and motivation to learn (Dole et al., 2017). Using PBL in the classroom can lead to higher levels of student understanding (Firdaus et al., 2017) and promote student empathy with the content (Grosseman et al., 2014). Adding a non-immersive virtual environment to elementary students' PBL experiences showed growth in their questioning skills (Hung et al., 2014), implying technology positively impacted learning in a PBL setting (Dondlinger et al., 2015). 2D video has also been found to provide an authentic learning context as an instructional hook and research source (Aronis, 2016).

2.2 The Hypothetical Model of Immersive Cognition (HMIC)

According to the HMIC proposed by Ladendorf et al. (2019), IVR potentially combines the analysis of strong visual stimuli with embodied memories to deepen the learning process and learner engagement. It is proposed that the visual stimuli activate multiple channels in the brain, bypassing the working memory, and bringing both cognitive and embodied memories to the forefront from long-term memory. IVR allows users to experience a deeper sense of presence over a desktop computer or mobile device alone due to the 3D-360˚ view (Ladendorf et al., 2019; Rupp et al., 2016). The first-person point-of-view heightens this sensation by allowing the user to take on a semi-live position within the IVR content (Scoresby and Shelton, 2011). It is hypothesized that IVR could pull both cognitive knowledge and embodied memories of physical sensations, potentially creating a more engaging and motivating learning experience (Ladendorf et al., 2019).

3 Methodology

3.1 Site and Participants

This descriptive case study was conducted at a Midwestern K-5 elementary school that serves students aged 5 to 11. All students receive a daily 30-minute STEM-

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focused PBL class. Eight 4th grade students, five boys and three girls between the ages of 9 and 10, participated in this study. Six participants were White, one Hispanic, and one Asian and all were native English speakers.

3.2 IVR Experience

The IVR experience was implemented into a previously developed PBL problem scenario: “Our local zoo needs to revamp their habitats and audience experiences. What habitat designs and audience experiences can you recommend to the local zoo representative?” Participants researched an animal and habitat, wrote a final report, and engineered a model of their proposed habitat. IVR was used as an authentic source.

Participants used the school’s IVR kit which consisted of 24 iPod Touch devices, 24 Vibe viewer HMDs, and 2 iPad devices. The IVR experience lasted three days. Participants were introduced to the IVR kit and explored a zoo habitat on day one. Participants were given a research sheet specific to their chosen animal with IVR resources to explore on days two and three.

3.3 Data Collection

Observational data was video recorded and transcribed for conversations and movements. Participants were interviewed individually one week after the IVR experience for 20-25 minutes each using Seidman’s (2013) 3-part interview methodology as a framework.

3.4 Data Analysis Procedures

All transcriptions and student artifacts were coded over three phases. The ICAP rubric was used to analyze the participants’ cognitive and collaborative behaviors identified in RQ2 (Chi and Wylie, 2014). The rubric was edited to include the IVR behaviors of movement, choosing content, observations, and questioning

Table 1. ICAP Rubric (adapted from Chi and Wylie, 2014, pg. 221)

Learning Behavior	Description
Interactive (dialoguing)	Debating with a peer about the justifications based off IVR experience; discussing similarities and differences between IVR experiences with a peer
Constructive (generating)	Explaining concepts from the IVR experiences in their own words; comparing and contrasting IVR content to prior knowledge or other IVR content; asking questions beyond clarifications
Active (manipulating)	Manipulating the IVR by choosing experience, moving 360˚, looking around; interacting with the IVR content by reaching out, walking, or talking; asking clarifying questions; making verbatim or summarizing observations of the IVR scene
Passive (receiving)	Watching IVR with no movement, verbal questions, and verbal observations made

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3.5 Data Validation

A second coder was utilized to establish inter-rater reliability (IRR) at r=81.15% using Miles and Huberman's (1994) percentage agreement method. Participants also reviewed the emergent themes in a focus group setting.

4 Findings

Two main themes emerged from the data analysis: IVR content and lesson structure impacted participants' perceptions of their engagement (RQ1, RQ2a, RQ2b), and the participants' interactions with the content, each other, and the types of questions and observations indicated the level of engagement when compared to the ICAP framework (RQ2a-e).

4.1 IVR Content and Lesson Structure Impacted Peer Interactions

Purpose of IVR in the Instructional Design. The participants indicated they wanted to utilize IVR experiences for the purpose of inquiry. They wanted to explore and discover answers with IVR content they have never seen and use the experience to develop their own understandings. The participants viewed IVR as the vehicle for the content, but not the central focus of their learning.

Participants felt they wanted IVR used at specific times during the instructional sequence. One participant, Emily stated multiple times she should have preferred to start with the IVR as an instructional hook versus a new resource in the PBL cycle. "*I think that when we flip those two, the research we're going to have to read it anyway so it wouldn't have made a difference. Cause me and [my partner] found the basics everywhere and in the VR*." IVR as an instructional hook would have given Emily more focus for the upcoming research. Placing the IVR in the middle of the research process led to feelings of disengagement and boredom. *"…we would have learned more if we started from the introduction…yeah, you kind of get to look at the area and the zebras and feel like you get to know it…it's the same stuff we already saw like the stuff that we have the same info for, like from every website.*" Emily also indicated multiples times they were behind on research and the IVR set them further back. While other participants did not corroborate this statement in interview, all agreed with this theme during the focus group.

IVR's Impact on Student-Student Interactions. Six of the participants indicated they would want to utilize IVR with a partner again. These six relied on their partners for troubleshooting and sharing observations. Participants were observed physically moving their partners' bodies and heads towards a detail they had observed. The participants and partners exhibited a sense of excitement that fed off each other. If one partner was excited, the other became interested and immediately began looking. The participants also wanted to share what they were observing and receive immediate feedback. If the partner was not available, the participant reached out to a new person to share. Some participants went so far as to seek out the teacher just for the sake of sharing the IVR experience.

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Two participants cited specific frustrations with their partners that would lead them to not want one again. In one case, Adam's partner left him multiple times to be with other groups and view different animals, leading to frustration an unengaging experience. In a second case, Laura was frustrated with her partner who was not adept at using the IVR goggles and confused by the content. Laura had to redirect her partner, troubleshoot, and explain the content multiple times. Her partner was not allowing Laura to dive as in-depth into the IVR content and hindered her learning.

4.2 Learning Behaviors with IVR

Movement in IVR. Observed movement included 360˚ head and body movements, reaching out and walking (see Table 2). The manner and speed in which the participants moved their heads and bodies to view the 360˚ content changed as the experience progressed and new content was introduced. Participants used fast head and body movements with new IVR content and slower movements with previously observed content. Reaching out or attempting to walk towards the objects was not as noticeable in subsequent viewings. Their focus changed from taking everything in as quickly as possible to looking at a few specific details in additional viewings.

Table 2. Movements

	Students	Times Observed
Reaching	6	19
Walking	8	43

Observations, Questions, and Conclusions during the IVR Experience. Participants made two distinct types of observations during the IVR experience: in-the-moment while immersed (ITM) and after-the-fact without IVR (ATF) observations. ITM observations were clarifications and immediate wonders while ATF observations were reflective and pointed out specific details (see Table 3).

Table 3. Observation Style Comparison

In-the-Moment Observations	After-the-Fact Observations
Oh wow! Look at that! Oh my god, I see the leopard! Wait, where am I? I'm on a rock! Leopard!	So we need glass around the enclosure. Lots of space in there. And benches. A lot of enclosure. Yeah, because when you think about it there are a lot of enclosures. They close off the giraffes, the elephants, all the animals.

Included in the observation count in Table 4 were questions participants asked. Participant questions were focused on gaining clarity in what they were observing such as, "What is that?", and "Where am I?" and not asking deeper questions about the content.

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Table 4. Observation Count

Observation Style	Observations	Percentage of Total Observations	Conclusions Drawn
In-the-moment	327	68.99%	20
After-the-fact	147	31.01%	48

A chi-square test of independence was performed revealing a moderate relationship between the categories at *a*=.05 (X^2(1, N=542)=40.437, $p < .001$) and a low effect size using Cramer's *v*=.273, suggesting that there were many more ITM observations when compared to ATF observations (see Table 4). Participants were able to draw conclusions verbally from both styles. ITM and ATF observations that resulted in conclusions did not differ in style or details. More conclusions were drawn with ATF observations, indicating the need for time outside of the IVR experience to reflect. Questions were used as observations and clarifications.

ICAP Analysis of Learning Behaviors. Learning behaviors were analyzed using the ICAP framework. "Observations and questions" were participant observations of and questions about the IVR content. "Movement and interacting with IVR" were moments participants physically moved, looked around 360˚(see Table 5).

Table 5. ICAP Analysis

Student Activity	Interactive	Constructive	Active	Passive
ITM and ATF Observations & Questions	47 9.92%	47 9.92%	380 80.16%	0
Moments of Movement and Interaction with IVR	0	0	229 96.22%	9 3.78%
Total	47 6.60%	47 6.60%	609 85.53%	9 1.26%

A chi-square test of independence was performed to analyze the frequencies and relationships between the ICAP levels and student activities, revealing a significant relationship at *a*=.05 (X^2(3, N=712)=69.894, $p < .001$). A medium effect size was detected using Cramer's *v*=.313. Only 9 instances of passive receiving were found, where participants watched the IVR content with no movement or verbal observations. These moments occurred immediately after participants had been actively looking around the IVR environment and found the specific detail to stop at.

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5 Discussion and Implications

Elementary students perceived IVR as a useful tool in PBL. They preferred IVR videos to static scenes, supporting Aronis' (2016) study of traditional video as a vehicle for authentic learning in PBL activities. The participants perceived IVR as having a place in PBL possibly as both an instructional hook and primary source. Hung et al. (2014) found similar results with non-immersive VR used for scaffolding and support. Instructors and instructional designers must be purposeful in the incorporation of IVR in PBL learning activities, paying attention to the placement of the resource in the PBL cycle.

The participants made both ITM and ATF observations and were able to draw conclusions from both observation styles. More conclusions were drawn with ATF observations despite the fact that fewer ATF observations were made. This suggests the time outside of the IVR environment was necessary for participants to reflect and draw conclusions. Despite participants showing frustration when told to leave the IVR environment, the number of conclusions drawn were higher when participants were not immersed compared to full immersion. The time given for review and reflection could possibly yield more generation of conclusions. When observations and movements were combined, only 1.26% of the observed learning behaviors were rated as passive, which was done after participants had manipulated the scene to find a detail to focus on, implying that learning with IVR is naturally active. While IVR inspires active learning behaviors, it does not seem the behaviors will be higher-level. Instructional scaffolding is needed to support students in this endeavor (Hung et al., 2014).

5.1 Limitations and Future Research

Only eight participants were used in this case study at one site. The IVR resources in this study were limited to mobile applications available from the school district. The study was also limited to PBL as the instructional design.

Future research should be conducted on the impact of authentic IVR content on students' responses. Content designers would also benefit from research comparing students experiencing new IVR content versus previously learned material on content understanding and engagement. Research should also focus on IVR content and instructional designs that support students in inquiry learning behaviors. Finally, future research should expand on active learning with IVR.

IVR has the potential to provide an authentic learning activity in PBL and other learning designs. The field of literature needs to continue to expand, and to include the voices of learners form all ages. It is through their voices that K-12 educators and content developers will be able to truly meet their needs with IVR technology.

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