Investigating Engagement and Flow With A Placed-based Immersive Virtual Reality Game

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Abstract. An immersive Virtual Reality (iVR) game for high school students to learn about locations in their watershed with a primary focus on their city was designed and developed, employing a design model that focuses on flow. An exploratory study with the iVR game was conducted in an urban school in the eastern USA with 57 adolescents ages 16-18 from a population that is economically disadvantaged and includes students who are typically unengaged in traditional school-based learning environments. After game completion, the participants completed a 10-item survey measuring elements of flow and a 12-item survey designed to measure perceptions toward learning with VR games, immersion and presence. Participant focus groups were conducted with an emphasis on features that promoted engagement, learning, immersion and presence. The findings revealed that all students experienced a flow state when they played the iVR learning game. Almost all users (98.1%) had positive attitudes towards using the iVR game. Students experienced high immersion and presence. In addition, students had favorable attitudes towards learning with iVR games in school environments.

Keywords: Virtual Reality, Learning Game, Engagement, Flow, Place-based

Introduction

Learner engagement is critical to STEM education. This is especially true for high school students who are typically underrepresented in STEM-related fields. In the United States, traditionally underrepresented individuals in STEM-related fields include individuals from non-dominant racial, ethnic, and economic cultural backgrounds such as low-income, Black, Latino, and English-learning populations (Burke, 2007; National Science Foundation National Center for Science and Engineering Statistics, 2019). In U.S. high schools, many students from these populations are unengaged learners who are not concerned with achievement in school, avoid challenging work, and often do not complete learning tasks (Sanacore, 2008). The level of engagement with adolescents in urban school settings can vary with traditional teaching and learning experiences that include didactic, lab, and field experiences. Classroom learning environments have many distractions that include off-task conversations, cell phone use, and gaming on laptop computers. In secondary urban classrooms, many learners are not engaged or motivated to learn. They are satisfied to "just get by", and are at-risk for dropping out of school (Protheroe, 2004). Digital learning technologies including games have shown promise to promote motivation in learning with students from non-dominant racial, ethnic, and economic cultural backgrounds (Acquah & Katz, 2020; Aldolphs et al., 2018; Butler, 2016). To address this, we designed and developed a prototype of an immersive Virtual Reality (iVR) game for secondary learners about a STEM-related topic: locations in their watershed with a primary focus on their city.

We use the term iVR to refer to an interactive computer-generated experience that takes place within a simulated environment using VR headsets to generate realistic images and sounds and handheld controllers that allow interactivity to simulate a user's physical presence in a three-dimensional virtual environment. A person using headset-based iVR is able to move and look around in an artificial world and interact with virtual features or items in a classroom environment without distractions. While we recognize that VR experiences that are delivered via desktop computers have been referred to as immersive in the published literature, we contend that non-headset VR experiences are highly susceptible to distractions in classrooms with unengaged learners.

The majority of published research in the area of iVR with headsets has focused on design elements for developing immersion and a sense of presence (Jensen & Konradsen, 2018).

Immersion is the level of sensory fidelity that a VR system provides and describes the experience of using iVR technology (Slater, 2003). This technology works by exchanging sensory input from reality with digitally generated sensory input, such as images and sounds (Freina & Ott 2015). Spatial immersion is a term used in VR gaming and occurs when a player feels the simulated world is perceptually convincing; it looks "authentic" and "real" and the player feels that he or she actually is "there" (Jennett et al., 2008). Presence is a user's subjective psychological response to a VR system where the user responds to the VR environment as if it were real (Sanchez-Vives & Slater 2005).

Features of iVR gaming environments can include depictions of naturalistic, yet safe environments; compelling representations of real-world situations and interactions; and autonomous control of the user experience. These features can provide a sense of authentic immersion and presence of being physically at specific geographic locations (Jennett et al. 2008) and thus increase users' engagement and learning. Furthermore, iVR environments can incorporate a wide variety of media, including authentic imagery, text, data displays, animations, video content, and audio narration. Since iVR technology allows for such supports in an immersive environment, it can be designed to provide improved access to STEM-related content for both non-native English speakers and those with mobility disabilities or transportation issues who are physically unable to visit less accessible locations. Furthermore, iVR technology makes it possible for learners to experience geographic locations or situations that are inaccessible due to logistics (they are difficult to get to), risk factors (they are dangerous to visit), or history (they have ceased to exist).

Game-based iVR learning activities are inherently interactive. Games have potential to advance multiple science learning goals, including motivating students to learn science, advancing conceptual understanding of science topics, developing science process skills, and identifying with science and science learning (National Research Council [NRC] 2011). Games can spark high levels of engagement, encourage repetition and practice, and motivate learners with challenges and rapid feedback (Clark, Nelson, Sengupta and D'Angelo 2009). Studies have demonstrated the potential of digital games to support learning in terms of conceptual understanding (e.g., Barab ey al., 2007; Klopfer et al., 2009), process skills and practices (e.g., Kafai et al, 2010; Steinkuehler & Duncan, 2008), epistemological understanding (e.g., Squire & Jan, 2007; Squire & Klopfer, 2007), and players' attitudes, identity, and engagement (e.g., Barab, et al., 2009; Dieterle, 2009; Ketelhut, 2007). In the literature, effective games are described as interactive (Vogel et al., 2006), directed toward a clear and challenging goal (Malone 1981), highly engaging (Annetta et al., 2009), and able to promote high levels of learning (Girard et al., 2013). In addition, a review of numerous research articles of 3D multi-user virtual worlds found that game-based and narrative contexts promoted student engagement and science content learning (Pellas et al., 2017). The literature base on iVR and game-based learning have clearly identified the many affordances of iVR and the potential for effective game-based learning in STEM; a necessary next step is to articulate a theoretical framework and learning model for STEM-related game based learning using iVR.

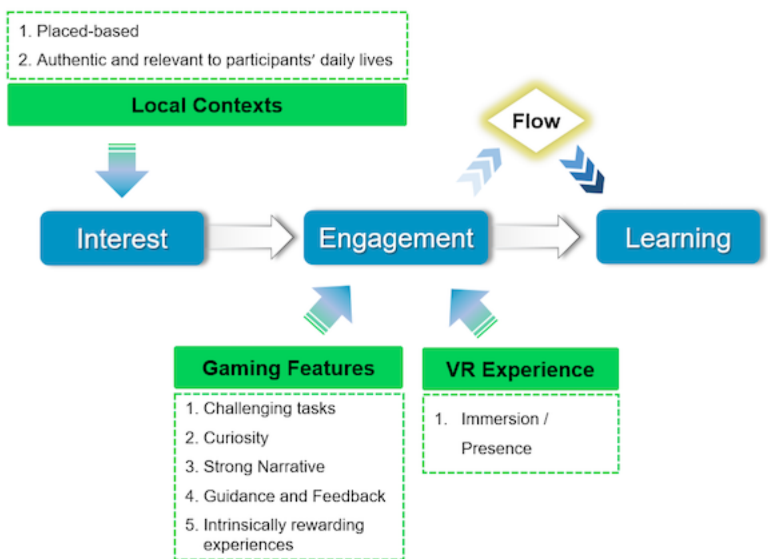
iVR Learning Model and Theoretical Framework

Place-based learning can occur not only in physical facilities such as schools and museums, but also in virtual spaces such as Web-based and virtual environments (NRC, 2009). Sociocultural perspectives argue that the features, materials, and activities associated with specific places centrally influence learning processes and outcomes. According to Hutchins

(1995), artifacts play an important role in distributed cognition for interaction with individuals as well with groups. The expert use of artifacts (e.g., a scientific representation of data in a virtual space) for understanding the landscape, water, and the spatial patterns and relationships of geographic features in a watershed can be viewed as a desired form of intelligent human performance (Hutchins, 1995). The use of VR artifacts that mediate learning and desired performance in specific contexts and places is regarded as a "practice turn" in theoretical accounts of human learning, development, and performance (Jessor, 1996; Rogoff, 2003; Shweder, 1996). In this view, virtual learning materials and objects, including visual representations of data and locations, constitute the foundational resources through which people individually and also collectively engage in learning activities.

Our iVR learning model (Figure 1) focuses on elements that lead to engagement and learning with iVR game-based experiences. Engagement can be defined as one's focus, participation, and persistence within a task, and therefore related to adaptive or self-regulated learning (Dorph et al., 2016). Engagement also refers to the experiential intensity of a relationship or interaction and one's temporal involvement or interactions with activities in an immediate environment (Shernoff, 2012). Engagement is what happens during a task or experience, a result of the interaction between the learners and the characteristics of both the task itself and the supporting environment. Dorph et al. (2016) discussed three dimensions of engagement: (1) behavioral engagement that focuses on whether a person is actively participating in a learning task or doing off-task behaviors; (2) cognitive engagement that focuses on thought processes or attention directed at processing and understanding the content in a learning task; and (3) affective engagement that includes one's emotions that are experienced during a science activity. Research suggests that a combination of these three aspects of engagement supports students' learning (Fredricks et al., 2004) and all may be enhanced by iVR. In addition, agentic engagement, a more recent aspect of learner engagement, refers to students' constructive contribution and proactive behaviors into the flow of the instruction they receive (Reeve, 2013; Reeve & Tseng, 2011). In an iVR learning environment, learners may have autonomous control to intentionally select a pathway that personalizes their learning to achieve the task.

Figure 1. *Immersive VR model*



Our project draws primarily from three theoretical frameworks (a) Malone's theory of intrinsically motivating instruction (Malone, 1981), (b) flow theory (Csíkszentmihályi, 1996), and (c) science learning activation theory (Dorph et al., 2016). These three theories of motivation and engagement form the basis for our design of iVR game-based learning activities to promote user engagement and learning.

Malone's theory of intrinsically motivating instruction (Malone, 1981) argues that intrinsic motivation is created by three qualities: challenge, fantasy, and curiosity. Challenge depends upon activities that involve uncertain outcomes due to variable levels, hidden information or randomness. Goals should be meaningful to learners, since they need some form of performance feedback to tell whether they are achieving their goal. For an environment to be challenging, the outcome must be uncertain. Fantasy should depend upon skills required for the instruction. For example, in an iVR environment, this might involve a learner "flying through" a watershed to visit different locations in various points in time. Curiosity can be aroused when learners believe their knowledge structures are incomplete. According to Malone's theory, intrinsically motivating activities provide learners with a broad range of challenge, concrete feedback, and clear-cut criteria for performance. Thus, to engage a learner's curiosity and learning, feedback should be both surprising and constructive.

Flow is an optimal psychological state in which a person performing an activity is fully immersed in a feeling of concentrated focus and enjoyment in the process of the activity (Csíkszentmihályi, 1996). People experience flow when engaged in an activity that is appropriately challenging to one's skill level. According to Shernoff et al. (2003), student engagement has been conceptualized phenomenologically, on the basis of flow theory, as a simultaneous experience of heightened concentration, enjoyment, and interest. These components are strongly related to the experience of learning (Shernoff & Csikszentmihalyi, 2009). From this view, optimal iVR learning environments can be designed to incorporate perceptions of value, relatedness, agency, control, and autonomy in addition to other conditions for flow experiences such as the appropriate match of challenges to users' level of skill, goals, and feedback.

Flow theory has been a theoretical base for exploring educational video and digital learning games because of participants' sense of immersion, which can result in a deeper engagement with learning (Shernoff, 2012). These games are purposefully designed for the achievement of learning goals through flow-like experiences (Fu et al., 2009). Research in the area of ~~serious~~ education games have reported specific flow components such as challenge (Hamari et al., 2016), time transformation (Wood et al., 2007), positive affect (Wang et al., 2008), and motivation with players in game environments (Huang, 2011). In addition, players' sense of time loss was found to be associated with the game's complexity, use of multi-levels, missions, multiplayer interactions, and narrative (Wood et al., 2007). Other game-based studies reported that players engaged in scientific practices with a forensic science augmented reality mystery game achieved a substantive flow-like experience through a sense of discovery and desire for higher performance (Bressler & Bodzin, 2013; 2016).

A main component of science learning activation theory (Dorph et al., 2016) contends that the activated science learner is fascinated by natural and physical phenomena. A learner can have emotional and cognitive attachment or obsession with science topics and tasks that serve as an intrinsic motivator towards various forms of participation. This includes aspects pertaining to curiosity (Litman & Spielberger, 2003) and interest or intrinsic value in science out of school (Baram-Tsabari & Yarden, 2005). It also includes positive approach emotions related to science, scientific inquiry and knowledge. Each of these constructs were found to be associated with engagement during science learning (Hidi & Renninger, 2006).

Given the potential of iVR to create a paradigm shift in education (e.g., Makranskya et al., 2019) and the availability of low cost non-tethered VR headsets such as the Oculus Go (USD $149), we were interested in investigating if an iVR game focused on learning about features in the local environment would engage U.S. high school students who are typically underrepresented in STEM-related fields. In addition, we were interested in understanding students' perceptions of learning with iVR games. This exploratory study was guided by the following research questions:

1. Do urban high school students experience a state of flow when they play an iVR learning game focused on local features in their watershed?
2. What are urban high school students' perceptions of learning with an iVR game?

Design and Development of the iVR Game

We designed a watershed VR environment using Unity and built the game for Oculus Go headsets. Our VR space includes a map-based interface using 3D map with labels, realistic models of objects, topography, and terrain. We used the Oculus Standard Development Kit input module and customized some C# scripts to enable the learner to "fly" through the VR environment using the headset and the controller. The prototype version for this study included navigational and map aids; UI elements such as buttons, pictures, and text; highlighted key vocabulary text; and attention to accessibility (e.g., avoiding green and red interface elements, which are problematic for color-blind users).

We used a series of design principles to promote learning with diverse learners within the VR environment.

1. *Situate learning experiences in the local environment* (NRC, 2009). The learning experiences reflect a view of science that is influenced by individual experience as well as social contexts. Science learning is fundamentally a cultural process that is viewed as an activity in which conceptions of learning are locally situated (Nasir et al., 2006; Rogoff, 2003). Supports were embedded for participants to interpret their learning experiences in light of prior knowledge, experiences, and interests.

2. *Design for diverse populations*. Environments were developed in ways that expressly draw on participants' cultural practices, including everyday language, linguistic practices, and local cultural experiences (NRC, 2009). The contexts helped learners identify in personally meaningful ways (DeBoer, 1991) that promoted connections between their personal lives, experiences, and science knowledge (Calabrese-Barton, 1988).
3. *Use multiple and varied representations*. To promote deeper understandings and sense-making of concepts through concrete, sensory, and immersive experiences (NRC, 2009; 2011). We use combinations of imagery, 3D visualizations, animation, audio and text to enhance learning and transfer (Mayer, 2009; NRC, 2009; NRC, 2011).
4. *Engage learners in challenging tasks*. Distinct challenges within a learning game keep learners engaged and challenged. Designing for the right challenge-skill balance promotes engagement and an intrinsically rewarding experience for the learners (Bressler & Bodzin, 2016).
5. *Make tasks authentic*. To make science learning engaging, we designed the iVR module so students felt the relevance and authenticity of the learning activity (Kirriemuir & McFarlane, 2004). Authenticity means that the problem or issue that learners are engaged in is something they understand and relates to their lives in some way (Klopfer et al., 2018).
6. *Provide a strong narrative*. A game designed for both formal and informal use requires a strong narrative content to generate excitement, interest, or enthusiasm for science learning (NRC, 2011). Narratives as "mystery" that use a question, problem, or mission can enhance learner motivation (Gustafsson et al., 2009; Wilson et al. 2009).
7. *Provide supportive guidance and motivational feedback*. Guidance in the form of advice, feedback, prompts, and scaffolding can promote deeper learning (de Jong, 2005; Azevedo &

Aleven 2010). Providing guided exploration and metacognitive support also enhances learning for transfer in informal settings (NRC, 2011). Support was enhanced by different forms of engaging feedback types such as badges or points (Pirker et al., 2016).

In the iVR game, students are first introduced to the game's contextual challenge. They are volunteering to help out at the Lehigh Gap Nature Center (LGNC) to get equipment and arrive to a locked door. The key has been lost at one of nine featured locations in the watershed. They must go to visit all locations with a drone and correctly identify each one to retrieve the key. Then the location game begins. Instructions are given on how to use Oculus Go controller and headset to move in the VR environment, the use of navigational tools, and to interpret map indicators (Figure 2). When the player selects a target location, a pop-up panel appears on the left side with the question "What is this place? Four-choice buttons appear on the right side, and an embedded window with a top view of the camera appears in the center to provide a better reading of the map (Figure 3). If an incorrect answer is chosen, visual and textual hints focusing on scientific or socio-environmental aspects of the location appear, prompting the player to try again. For example, if a student is unable to identify the wastewater treatment plant, the hint states, "This facility is between the Lehigh River and the Little Lehigh Creek" and the adjacent creek in the iVR map environment is highlighted (Figure 4). When the correct answer is selected, an icon specific to that location appears on the badge board (Figure 5). After completing the board with all nine icons the key is always found at the last location, regardless of order the sites were identified. The user's last mission is to return to the LGNC and open the door.

Figure 2. *Image of iVR game displaying navigational tools and three locations*

Note. The navigational feature on the upper left displays a zoomed in aerial view. The navigational feature on the upper right is a directional compass eye. The eye points in the direction of the user's gaze.

Figure 3. *Pop up panel prompting user to identify the location*

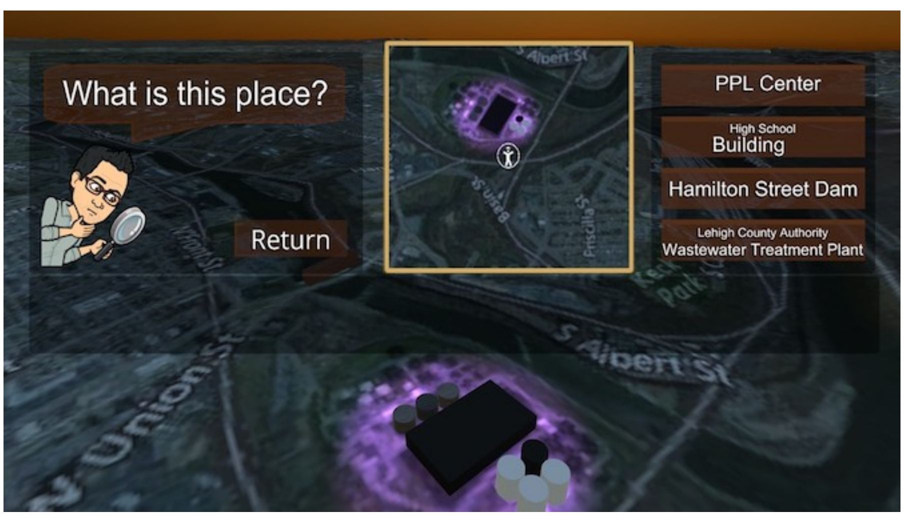


Figure 4. *Pop-up panel displaying a geo-contextual hint and activation of corresponding map layer*

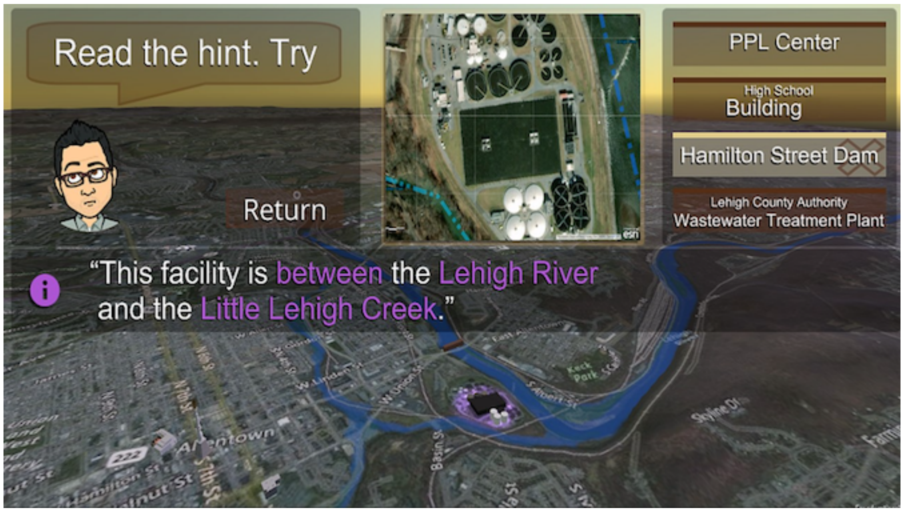
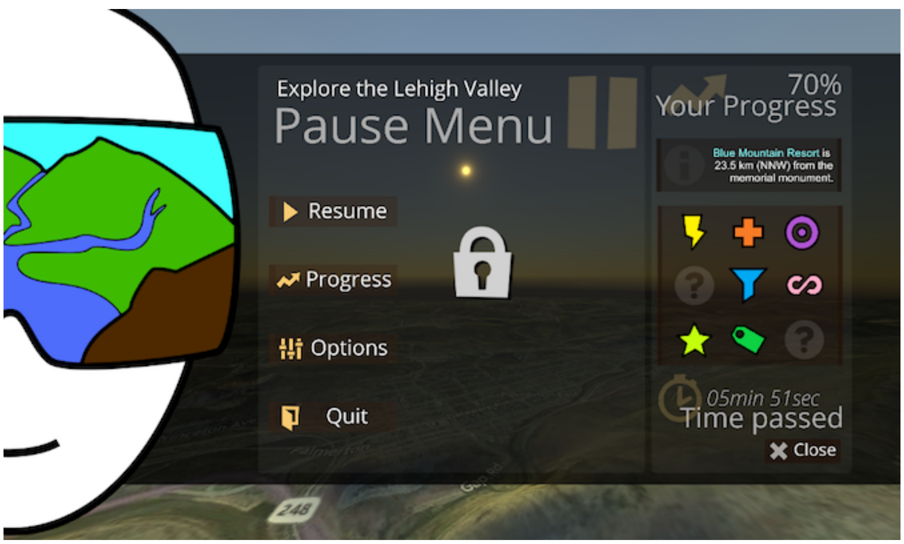


Figure 5. *Badge board displaying seven icons that correspond to the locations that have been identified*



Note. Elapsed time is also displayed

Methods

This exploratory study adopted a design research approach (Collins et al., 2004). Design research is particularly useful in the dual goals of advancing a general theory of how students are engaged in learning with an iVR game as well as improving the design of the specific iVR game. Due to the reciprocal process of theory informing practice and vice versa, design research utilizes an iterative cycle to design the iVR learning game and understanding students' perceptions of their experiences at the same time. This study reports on the first prototype game.

The iVR game was implemented with 57 adolescents ages 16-18 from three environmental science classes in an urban school in the eastern USA. The sample included 42 males and 15 females. Two students had prior experience using VR headsets. At this school, all students were economically disadvantaged and received free breakfast and lunch. We conducted this study during the last month of the school year, a time when increased truancy and absenteeism occurs and students often do not complete classroom assignments. The iVR game was a functional prototype for the Oculus Go headset. The prototype included two software bugs in which users could not navigate in a straight line with the handheld controller from one location to the next and could only read pop-up screens by viewing them looking northwards. Six students at a time completed a two-day implementation sequence.

During the first the day, students completed an Oculus Go tutorial to get used to the VR interface and hand-held controllers. Students then explored educational games and immersive experiences that were placed on the VR headset. On the second day, students were given an overview of the iVR game and then they completed the game. After the students finished the iVR game, they completed two data collection measures. The first measure was a 10-item flow Likert-scale survey that measured elements of flow as outlined by Csikszentmihalyi (1996). Each level of the Likert-scale had a different numeric value with "I strongly disagree" equal to 1 and "I strongly agree" equal to 5. Possible scores ranged from 10 to 50. The survey was derived from the Short Flow State scale (S FSS-2) and the Core Flow State scale (C FSS-2) developed by

Jackson et al. (2010) and was previously used twice by Bressler and Bodzin (2013; 2016); Cronbach's alpha for the instrument in this study was 0.80. The second measure was a 12-item Likert-scale *Perceptions of Learning with VR Games survey* designed to measure attitudes toward learning with VR games, immersion and presence, and usefulness. The survey included items pertaining to attitudes towards using VR games (5 items), immersion and presence (2 items), attention (1 item), skill (1 item), perceived usefulness (2 items), and perceived ease of use (1item). Possible scores ranged from 12 to 60. Cronbach's alpha for the instrument in this study was 0.915. Despite the limited sample size, we tried conducting an exploratory factor analysis in SPSS (Principal Axis Factoring with Promax rotation). Two factors emerged, with 6 items in each, explaining a total of 64.53% of the variance (Factor 1- 54.26%; Factor 2 - 10.27%). The individual items for each of the two factors did not correspond to the subscales that were originally conceptualized – immersion and presence, and attitudes for using VR games.

During the implementation, two students experienced motion sickness and withdrew from the study. One student did not complete all survey items. The data analysis included 54 students, 41 males and 13 females, who each completed the responses to all survey items. All students were asked to attend a focus group that were scheduled by the environmental science teacher in groups of six students. Due to absenteeism and truancy, 17 students did not attend the scheduled focus groups. Nine focus groups were conducted with 38 students after all implementation days were completed. The focus groups included 32 male students and 6 female students. The number of students attending each focus group varied from two to six participants.

The focus groups questions (see Appendix) centered on students' perceptions of learning with an iVR game with an emphasis on features that promoted engagement, immersion, presence, and learning. Each focus group was digitally recorded and transcribed into an MS

Word document. A content analysis on the transcribed discourse was performed and examined with a focus on the meaning and implications for the second research question (Krippendorf, 2004). Such content analysis enables a systematic coding of data by organizing the information into categories to discover patterns (Treadwell, 2017). An initial set of categories related to past user perception studies from the virtual reality literature was created. These categories included gaming context, presence, interactivity, ease of use, immersion, engagement, and interface. We also added placed-based and nature of learning to our initial category labels since these topics were discussed in the focus groups. Category labels were defined. A set of rules for coding passages that included at least one sentence of text discourse was agreed upon by the researchers. Coding occurred manually without the aid of a computer program. One of the researchers initially coded the focus group transcriptions. Additional category labels emerged during the process. Two other researchers systematically re-analyzed the coding of the focus groups. More category labels emerged during this process and were defined. The resulting coded passages were discussed and agreed upon by all researchers. One of the researchers then compiled and tallied the identified examples of each code.

Results

The findings revealed that all students experienced a flow state when they played the iVR learning game. The total flow measure mean was 41.67 with a standard deviation of 5.67. The total score responses ranged from 31 to 50. Table 1 displays the flow survey item results. During the game play, students were very quiet at all times while their headsets covered their faces. They rotated their chairs in different directions and moved their heads as they viewed their virtual environment. The participants also pointed their controller in different directions as they aimed at location objects in the game and selected responses to questions.

Table 2 reports the perceptions of learning with VR survey item results. Almost all users (98.1%) had positive attitudes towards using the VR game. The total perceptions of learning with VR games survey mean was 53.46 with a standard deviation of 6.47. The total score responses ranged from 33 to 60. The student responses noted that they experienced immersion and presence. Students responded that the iVR game helped them learn and the game made learning more interesting. In addition, students responded with favorable attitudes towards learning with iVR games in school environments. Table 2 displays the means and standard deviations for each item from the perceptions of VR for learning survey.

Table 1

Flow Survey item responses (n=54)

Description of Item	Mean	SD
I was challenged, and I felt I could meet the challenge.	4.13	0.94
I did things naturally without thinking too much.	4.15	1.02
I had a strong sense of what I wanted to do.	4.46	0.69
I felt I was on track towards my goals.	4.43	0.77
I was totally focused on what I was doing.	4.56	0.66
I felt in control of what I was doing.	4.17	0.96
It felt like nothing else mattered.	3.72	1.12
I lost my normal sense of time.	3.70	1.14
I really enjoyed what I was doing.	4.43	0.76
I was in the zone.	4.37	0.71

Table 2

Students' Perception of Virtual Reality for Learning item responses (n=54)

Description of Item	Mean	SD
I enjoyed using the Virtual Reality (VR) game.	4.76	0.47
I felt that the Virtual Reality game helped me learn.	4.33	0.82
I would like to use VR games for learning in the future.	4.57	0.75
I believe using VR games in school is a good idea.	4.65	0.59
Using VR games makes learning more interesting.	4.61	0.63
I felt like I really was there during the VR game.	4.26	0.94
My seeing and hearing senses were fully used while in VR.	4.13	1.01
I felt the Virtual Reality game held my attention.	4.42	0.80
I felt I could move better in the game the longer I played.	4.41	0.81
I believe VR games can be helpful for learning.	4.59	0.66
Using VR games can improve my learning in school.	4.39	0.76
Learning to use Virtual Reality is not a problem.	4.59	0.66

The focus group content analyses findings revealed specific features that the students liked best about learning with the iVR game. These included the gaming context (10 coded responses), a sense of presence (8 coded responses), the game being placed-based in the students' city and surrounding areas (7 coded responses), a novelty of learning (6 coded responses), the interactive nature of learning (6 coded responses), ease of use (6 coded responses), immersion (5 coded responses), and being focused on learning task (4 coded responses). The iVR game enabled students to see their city "from a different perspective" and changed students' "insight on the area that you are in." Students liked that the game "was a real place" and learned about new places they did not previously know. A gaming feature that was specifically noted by multiple students included "seeing progress" during gameplay which "helped with goal setting." Students also enjoyed "being able to move freely" and were pleased at having the autonomy to complete the tasks in any order. The iVR game provided a "real experience" where students were "immersed" and "felt like you are there". Students commented that the game was “fun” and “made you interested in learning.” Students also stated the game was “easy to learn” and it provided an environment where “you don’t get distracted easily.” Features of the iVR game that made participants feel immersed included the interactive nature and user control of the gaming experience (24 coded responses), the placed-based localism of the game (6 coded responses), presence (5 coded responses), and graphics (4 responses). Students specifically noted “being able to move at their pace” and the freedom to “look at different places”. Students also commented on the interactive nature of the navigational aids and how the movement of the user’s body corresponded to the movement of the directional compass eye (see Figure 2). Students noted that being in their city absorbed them into the learning experience as they discovered “places that I didn't even know.” In addition, students commented that the experience made them “feel like I was personally there.”

The ways in which the students perceived the VR games to help them learn included a variety of different types of learning experiences (31 coded responses), engagement and holding attention (7 coded responses), and the geography and navigation (4 coded responses). Students articulated the potential for many specific possibilities for learning using VR games and noted many specific curriculum topics including history, watching “the battle of Gettysburg” in VR, designing a house, creating art, learning how to drive a car, learning languages by “traveling to places where that language is spoken”, conducting a biology dissection or chemistry experiment. Students also commented that the game provided “a better way of how to understand the geography.” It helped them learn about maps and locations, and how to use a compass. One student stated “it made me more eager to learn because it was it was in a game form.” Students noted that the gaming environment was engaging and held their attention. One student specifically stated “it is hard not to pay attention when you have that [VR headset] on your face.”

The features of VR learning that held students' attention included immersion (9 coded responses), the game-like freedom to explore (8 coded responses), the interface (5 responses), placed-based nature (1 coded response), and the learning task (1 coded response). Students commented that being immersed in the game removed typical classroom distractions. A student stated, "that no matter where I looked, I was still in the game, and not focusing on anything else." The game also provided a sandbox environment for unstructured learner choice. As one student stated, "When I got the chance to explore the whole area of the game, it kind of helped me to like, explore and like learn new places and everything that I did not know."

Students learned many new things about their local geographic region and their city that they previously did not know prior to playing the iVR game. These included specific environmental-related locations such as the city's water filtration plant, the fish hatchery, dams in the river, and the two mountain ranges to the north and south of the valley. Students commented that there were area locations that they "could visit around here; that, I never really knew until I've seen this." In many focus group responses, students commented that the game re-scaled their spatial schema of their city. Some students thought their city was small, but appeared larger in the iVR game. Some thought their city was big, and it appeared smaller in the game. Some students commented that the game made features in their city seem closer to each other.

Compared to typical school activities, the students perceived VR as being an enhanced learning experience (18 coded responses), being more focused and having less distractions (12 responses), being more immersive (10 coded responses), more engaging (7 coded responses), more enjoyable (5 coded responses), and more interactive (3 coded responses). They articulated many specific science and social studies topics that they learned about in school that they thought would be more interesting to learn in VR. In addition, they noted a variety of other content disciplines including math, psychology, engineering, art, and English that they thought would be more interesting to learn with VR.

Specific features that the students did not like about learning with the iVR game included the two software bugs in the prototype that involved not being able to navigate in a straight line and the restrictive viewing of location pop-up screens (16 coded responses), the clarity of the map features (9 coded responses), symptoms of virtual reality sickness (5 coded responses), game design features of the hand-held controls and aerial placement of the user (3 coded responses), the lack of sound and narration (2 coded responses), and an easy level of difficulty (2 responses). Students were unable to navigate in a straight line due to a programming bug and had to “go a little bit to the right, or a little bit to the left” in order to get from one location to another. Students also had “to look a certain way to activate” the targeted locations. Some commented on “blurriness” of some of the map features as they navigated in the game. Five students reported symptoms of VR sickness that included initial disorientation, nauseous light-headedness, and headache. Three students who identified themselves as “gamers” noted that they did not like the simplistic movement of the hand-held controls and would have preferred being able to also move vertically within the VR environment. Three students commented that the level of difficulty was too easy and two students commented that sound and narration would have enhanced their learning experience.

Discussion

The findings from this exploratory study provide support that the iVR game promoted engagement and flow with urban adolescent learners. In the game, students were able to freely decide the order of locations to visit to complete the game tasks. The students also had the freedom to move freely and explore the VR environment on their own. Students reported that they enjoyed using the iVR game. Ghani and Deshpande (1994) stated that flow and high levels of enjoyment are correlated with exploration. Flow states are achieved when participants experience increased engagement when the perceived challenge of the task and their own skills are high and in balance, the learning tasks are relevant, and the learning environment is under their control (Shernoff et al., 2003). The study results supported that the game provided an appropriate level of challenge for most students' skill levels and afforded autonomy as they played the iVR game. It is possible that students were involved with agentic engagement during gameplay as they made their own exploration choices during the game experience. Analysis from the focus groups found that some students sought ways to add personal relevance to the learning activity by seeking out additional features in their local environment. When students act agentically, they initiate a process in which they generate for themselves options that expand their freedom of action and increase their chances of experiencing both autonomy and meaningful learning (Reeve & Tseng, 2011). Optimal iVR learning environments can be designed to incorporate perceptions of relatedness, agency, control, and autonomy in addition to other conditions for flow experiences such as the appropriate match of challenges to users' level of skill, goals, and feedback. Therefore, it appears that each of these game design features may have contributed to students' motivation for gameplay and contributed to their engagement and flow experiences.

The iVR learning model used to guide the design of the game focused on local contexts, gaming features, and the VR experience, all elements that likely led to student engagement and flow experiences. The game was designed to be placed-based and situated in the students' watershed with a particular emphasis on their city. Place-based educational contexts connects learners to their immediate environment (Gruenewald & Smith, 2014). Findings from the participant focus groups found that the placed-based, local nature of the game promoted enjoyment with the game, made some participants feel immersed, and held their attention. Students stated that they were interested in specific locations in their watershed and some commented that they would like to visit some places they newly learned about. Thus, curiosity was likely promoted for these students. Similar to other studies (e.g., Annetta et al., 2019; Bressler & Bodzin, 2016; Clark et al., 2009;), specific gaming features that included challenging tasks, a strong narrative, and motivational guidance and feedback were all design elements that likely contributed to students' engagement and flow. Immersion and presence were experienced by the students. During the game, learners experienced a sense of "being there", or being completely immersed in the iVR game environment. The findings from the flow survey and focus groups support that the participants experienced a form of immersion that was related to the experiences that educational video gamers encounter when they become totally absorbed in a game, and in doing so experience a sense of time loss and positive emotions (see Shernoff, 2012).

The second research question investigated urban high school students' perceptions of learning with an iVR game. Data results from the perceptions of learning with VR survey found that the iVR game helped the students to learn. The participants experienced the game as an enjoyable way to learn and stated they would like to use VR games for learning in the future. The students perceived that using VR games in school is a good idea and learning to use VR is not a problem. In the focus groups, students mentioned many specific curriculum topics that they envisioned VR could be used to help them learn. Students also reported that VR games makes learning more interesting. As noted above, a student stated that the iVR game made him "eager to learn." Students felt that using VR games could improve their learning in school. In fact, across every response in the focus groups, the students commented that VR had a relative learning advantage over typical school activities.

Students reported that the iVR game held their attention thereby keeping them on task. As one student stated in a focus group, "with VR, everyday things are less distracting, you can really focus on what you're doing." In urban high school classroom environments that include unengaged learners, there are many classroom distractions. These include off-task talking, cell phone texting, playing video games on laptops, and watching videos on electronic devices. The immersive experience within the Oculus Go headset provided students with a learning environment where "you don't get distracted easily." The headset provided students an engaging learning space that greatly minimized the ability of a student to participate in off-task classroom behaviors. This was captured in the focus groups and represented in the following student comment: "Because when I'm in class, I pull out my phone, I wouldn't even listen. But in the VR it's more different definitely because I have it on, and I'm more focused."

The findings from this study support that students were spatially immersed in the iVR game. The simulated iVR environment was perceptually convincing to the students. The place-based nature of the iVR game being localized in the students' lived environment provided students with a feeling of authenticity. The map-based interface included recognizable features such as high topographic ridges, township names, major and local roads, and the main river and streams in the watershed. The iVR environment was purposefully designed to emphasize local features that students were familiar with that included a city monument in the center of the city, the students' school, a local amusement park, the city's sports arena, and the largest shopping mall. These features helped to promote a sense of presence, the feeling that they were actually there. The inclusion of these geographic and place-based features influenced students' spatial schema of their city. In the iVR environment, we selected a Bing base map to use since it was freely available and included labels on many geographic features. Prominent features such as mountain ridges and the river were apparent to the players. However, while "flying" from one location to the next, some participants had difficulty reading specific street-level text information on the base map. To address this issue, in our next iVR game version, we plan to use Esri map interfaces, the CityEngine application, and additional geo-referenced data layers of watershed features to make spatial patterns and relationships such as distance, direction, and topologic relationships of geographic features in the watershed more apparent. We believe that making these geographic features more evident to the user as they play the game will enhance students' geospatial understandings of their watershed. In our next iteration of the study, we intend to investigate this further by having students draw sketch maps of their watershed before and after playing the iVR game. Such sketch maps can capture participants' spatial understandings of their watershed and its associated features (Boschmann & Cubbon, 2014).

There are implications for using iVR learning games in school environments. iVR games have much potential to engage urban high school students who typically are not concerned with achievement in school, avoid challenging work, and often do not complete learning tasks. In this study, students were engaged in learning during a time of the school year when increased truancy and absenteeism occurs. Given the affordability of non-tethered VR headsets such as the Oculus Go, there is much potential to enhance learner engagement in schools as more curriculum-aligned immersive VR learning experiences become available for student learning. The novelty of using a VR headset might also contribute to students' engagement as noted by this student comment: "I feel like, if we have VR headsets, in the schools, I feel like that absences of all the kids will go, like decrease, because every day is like something new." As with any new technology adoption for a school setting, a plan for classroom materials management will need to be put in place. In this study, playing a learning game with Oculus Go headsets was quite feasible in a room with six urban adolescent students and was easily supported by one member of our team. We believe that a ratio of one support person for ten high school students would be reasonable for implementation with these headsets. During the implementation, a small number of students experienced motion sickness. Out of our total sample of 57 students, two students (3.5%) experience motion sickness and could not complete the game. Five students (13.5%) experienced some degree of motion sickness but completed the game. In school settings, a desktop VR version of the game could easily be available for students who experience motion sickness. However, desktop VR game experiences may not be as immersive as a headset VR experience. Students using desktop VR games may be susceptible to typical classroom distractions that are prevalent in schools. In addition, desktop VR may not provide the same immersive situatedness and sense of presence that iVR affords.

Limitations

There are some limitations to this exploratory study. First, while our immersive VR model includes learning as an important component of the model, we did not measure this in this study. This study was designed specifically to investigate learners' engagement with a place-based iVR game and to determine if a flow state was achieved and to also understand the perceptions of learning with VR games with urban high school students that includes unengaged learners from a population of students typically underrepresented in STEM-related fields. In our next study, we intend to measure learning to fully test our immersive VR model. Second, our study was implemented with a small sample size of 54 high school students. One possible reason for the inconsistency in the exploratory factor analysis is that the small N for the factor analysis could have given an unstable factor structure. With a larger sample (for example, over 100 participants), the factor structure might change. Third, many fewer females than males participated in the study. Only 15.8% of the participants who participated in the focus groups were female. Female students were only present in four of the nine focus groups. Therefore, some of the perceptions reported in this study may be biased towards male viewpoints. Fourth, due to our small sample size, we did not use a comparison group study design to investigate differences between immersive headset VR game-based learning and non-headset VR game-based learning that occurs on a desktop computer. In a future study, we intend to investigate the differences between non-headset desktop VR and headset VR with regards to flow, immersion, presence, and learning.

Conclusion

We designed, developed, and implemented an iVR learning game in an urban school with a population of economically disadvantaged learners who typically are unengaged in traditional school-based learning environments. Our learning model focused on elements that lead to engagement and learning with iVR game-based experiences. In this project, we used the opportunities afforded by iVR, such as providing abstraction (e.g., 3D spatial markup to illustrate differences in local watershed features) to direct learners' attention and support learner engagement with exploring the local environment. Learning with game-based iVR provided a learning experience that was highly immersive, immediate, and personal by situating the learning in the participants' local environment. Adolescent learners demonstrated high levels of engagement and flow and had favorable perceptions with learning with iVR in school settings.

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Appendix. Focus Group Questions

1. What did you like best about learning with the VR game?

   - if "everything", prompt: tell us one thing that you really enjoyed.

2. What did you not like about learning with the VR game?

   - if nothing, "can you tell us one thing that you did not enjoy with the VR experience".

3. What features of the VR learning game made you feel engaged or immersed in the experience?

   - If "everything", tell us one thing specifically that made you feel like you were there?

4. How can VR games help you to learn?
5. Which features of the VR learning held your attention?
6. How did your experience with VR compare to typical school activities?
7. What do you now know about the geography of the Lehigh Valley that you did not know before?
8. What did you now know about your city that you did not know before?
9. Think about some of the science and social studies topics you learned about in school this year. Which topics do you think would be more interesting to learn with VR?

   - Which other school disciplines would you enjoy learning with VR?