

Watershed Explorers: A Digital Gameful Learning Experience

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Program Abstract

In partnership with informal environmental educators, we developed a desktop virtual reality digital gameful learning experience (DGLE) to learn about our watershed's socio-economic development since the mid-1800s, its industrial history, the spatial aspects of the watershed, and how it changed over time. We discuss implementing the DGLE with preservice and inservice science teachers.

Proceedings Abstract

This innovations paper describes a desktop virtual reality digital gameful learning experience (DGLE) developed collaboratively by university faculty and informal environmental educators to learn about our watershed's socio-economic development since the mid-1800s, its industrial history, the spatial aspects of the watershed, and how it changed over time. We provide background on place-based virtual reality and the affordances that DGLE can provide for learning. Next, we present *Watershed Explorers*, a place-based virtual reality DGLE that was developed for a wide range of learners, including adolescents through senior citizens, and envisioned to be implemented as a curriculum enhancement learning activity for classroom learners.

After developing the Watershed Explorers DGLE with partner environmental education (EE) centers, we conducted a usability study with our preservice and inservice teachers who were enrolled on our institution's secondary science methods course and our EE course during the Spring 2022 semester. The students completed *Watershed Explorers* and were asked to think of related themes for a shorter version that would have only 3 watershed locations instead of 9 locations. They completed a usability survey on the game's supportive features that included the game tutorial, journal log, media gallery, glossary, tool tips, conversation logs, and location panels. The students also responded to a survey about specific game features and their perception of learning with the DGLE. The students proposed four different 3-location versions of *Watershed Explorers* including a fish ladder theme, an environmental issues theme, an industrial history theme, and a general history theme. The students reported that the game narrative was clear and made sense, they discovered things about the watershed that they previously did not know, they liked using the game for learning about the watershed, they found the game and the game interface easy to use, and they did not feel overwhelmed by the amount of information that was presented. The preservice and inservice science teachers found the DGLE's supportive features useful but did not revisit them after they were first introduced. They recommended that after the second location was visited, the game should prompt the player to revisit the journal log, media gallery, and conversation logs and also remind the player that the glossary exists.

Introduction

Water is a paramount element to provide sustainable resources for humanity, industries, and the environment (McCarroll & Hamann, 2020). Nevertheless, studies have demonstrated that both children and adults have a poor understanding of water resources and systems that are mostly responsible for unsustainable water usage worldwide (The National Environmental Education & Training Foundation, 2000). The watershed concept is also misunderstood by people of all ages (Coyle, 2005; Covitt et al., 2009; Endreny, 2010; Shepardson et al., 2007). The U.S. Environmental Protection Agency (EPA) explains that “a watershed — the land area that drains to one stream, lake or river — affects the water quality in the water body that it surrounds. Because we all live on the land, we all live in a watershed — thus watershed condition is important to everyone” (EPA, n.d.). Moreover, learning about the history of places or environments, enables learners to better comprehend the spatial traits, ecological features, and environmental issues of the watershed in which they live.

Digital technologies can support learners to become genuinely motivated to engage in authentic learning (Clark et al., 2009). These types of technologies may foster self-directed and lifelong learning, which might eventually lead students to enhanced academic achievement (National Academies of Sciences, Engineering, and Medicine, 2018; National Research Council [NRC], 2000). Digital gameful learning experiences (DGLE) are promising tools to engage learners with school subjects (Bressler et al., 2019; Lamb et al., 2018) such as promoting spatial understandings of complex scientific concepts (e.g., watershed systems). Learning about watersheds with digital technologies has potential for refining learners’ perceptions regarding the impact human activities have had locally as well as globally over time. Thus, to help promote understandings of a local watershed, we designed and developed a multidisciplinary place-based

DGLE for desktop VR (dVR) called “Watershed Explorers” in partnership with four non-formal environmental education organizations. The game focuses on promoting learners’ understanding of the spatial components of a specific watershed while they learn about historical events and how the watershed has changed over time.

Digital Gameful Learning Experiences (DGLE)

The potential of using video games, digital learning experiences, and gamification approaches for education is well documented in the literature (e.g., Gee, 2003; Erickson & Sammons-Lohse, 2021; Klippel et al., 2020). DGLE encompasses gameful design, gamification, and game-based learning approaches that are implemented via digital means. Gameful design aims at stimulating one’s motivation to use a software (Tondello et al., 2019). Although the gamification concept is not new, the term “gamification ” is contentious in the literature (Seaborn & Fels, 2015). We view gamification as the utilization of game design techniques as well as game elements (e.g., dynamics, mechanics, components) in non-game contexts (Seaborn & Fels, 2015). Thus, DGLE are learning resources that include video games for skill development (Bediou et al., 2018; Mayer et al., 2019) as well as gamified mobile and virtual reality applications.

Studies have demonstrated the potential of DGLE in terms of conceptual understanding (Barab et al., 2007; Klopfer et al., 2009), epistemological understanding (Squire & Jan, 2007; Squire & Klopfer, 2007), players’ attitudes, identity, motivation, and engagement (Barab et al., 2009; Ketelhut, 2007), and enhancing learning (Checa & Bustillo, 2020). Moreover, games have promoted motivation in learning across non-dominant racial, ethnic, economic, and cultural backgrounds (Acquah & Katz, 2020; Bodzin et al., 2021). When examining moderators of student cognition, affect, and learning outcomes, Lamb et al. (2018) found DGLE approaches

being used across many different curriculum areas with increased results in students' learning performance.

Effective DGLE interventions can take advantage of “play” (Piaget, 1962). *Play* has a central role in students' learning by providing a safe-space devoid of correct or incorrect standards regulating one's behavior (Wasserman, 1992). Fun and engaged learning can be achieved by gameplay since games inherently encompass more than thirty learning principles including, discovery, multimodality, probing, and ongoing learning (Gee, 2003). Students usually do not fear failure during play, resulting in increased levels of agency and innovative thinking (Wasserman, 1992).

When thoughtfully designed, in-game scaffolds in DGLE (e.g., game interactions in contested situated places, question prompts, just-in-time feedback, and multimodal representations) contribute to science and environmental learning outcomes through the creation of risk-free, puzzling yet informative and enjoyable environments (Law & Chen, 2016; Li & Tsai, 2013). These scaffolds can engage students and support reasoning regarding scientific practices (Bressler et al., 2019). Moreover, DGLE can support new knowledge acquisition in meaningful ways, especially when students are in control of the subject at hand and feel capable of applying it to support further learning (Novak, 2010). However, many students have claimed science learning to be difficult and/or irrelevant to their lives (Jason, 2017), typically when they lack background knowledge to process abstract scientific phenomena or multidimensional systems such as watersheds (Corredor et al., 2014; Hodson, 2014). Therefore, using DGLE is a worthy way of stimulating students' motivation towards science learning (Bressler et al., 2019; Seaborn & Fels, 2015).

Place-based Education with VR

Place-based education focuses on better understanding one's environment, communities, and spatial context through teaching and learning situated in place (Semken et al., 2018).

Educators can leverage specific locales' unique traits and phenomena to promote learning based on students' lived experiences (Smith, 2002). As such, place-based VR games can encourage learners to apply their local knowledge about environmental issues to the given problem, besides challenging them to examine how scientific concepts (i.e., watersheds as complex systems) affect their communities (Squire & Jan, 2007). Local and regional personalization of learning can support students' agency by providing experiences regarding real-life issues and using learners' background knowledge to solve them (Vander Ark et al., 2020). Game designers can devise gaming features (e.g., maps, stages, avatars) to achieve an emotional connection between player and place (Jenkins, 2002). In educational settings, the application of place-based learning through the learners' acquainted contested spaces (e.g., discussions regarding land use and watershed management) can represent the foundation of game scenarios and narratives (Squire et al., 2003). Therefore, not only can place-based VR games assist the development of understandings about one's local region, but they may also foster learners' willingness to contribute to the well-being of their communities (Gruenewald, 2003).

Using place-based VR learning games holds much potential to help students learn about their watershed. Since VR is emerging in school and informal learning settings as an instructional technology, using place-based VR games can support environmental literacy education while nurturing learners' sense of place and belonging (Semken et al., 2018). Thus, to support students' understandings about their local watershed and its larger basin, "Watershed

Explorers” was designed as a place-based DGLE to be used as a curriculum enhancement learning activity.

Watershed Explorers

Watershed Explorers is a place-based DGLE and was developed for a wide range of learners, including adolescents through senior citizens. For classroom use, it was envisioned to be implemented as a curriculum enhancement learning activity and provides learners with an authentic challenge: The Delaware & Lehigh National Heritage Corridor (D&L) commissions the player to propose a top-three location plan for promoting tourism along the Lehigh River area. During a kayaking expedition downstream, players immerse themselves in real locations along the Lehigh River watershed while learning about the Lehigh Valley’s socio-economic development since the mid-1800s, its industrial history, the spatial aspects of the watershed, and how it changed over time.

Watershed Explorers begins by providing players with the game’s context and goal and the game tutorial. Players start the game in the D&L Welcome Center and meet four avatars that serve as virtual tutors and tour guides throughout the immersive exploration (Figure 1). Della-the-mule is the D&L mascot and coordinates the exploration team. Leni is the rivers and recreation specialist. Mira, the environmental educator of the group, describes the environmental importance and changes that occurred in the watershed area since the industrial revolution. Lance, a local historian, shares historical events of the Lehigh River during the past two centuries. After the avatars’ introductions, a narrated flyover animation of the Lehigh watershed map illustrates the path of their exploration downstream (Figure 2).

Figure 1. *Avatars in the D&L Museum Conference Room.*



Note. From left to right: Lance, Della (highlighted), Lenni, and Mira.

In the first location near the river headwaters, the avatars introduce the input controls in a tutorial. The game environment contains 360° high resolution photos enriched with videos, historical imagery, trail information signs, and narration regarding the historical or environmental importance of each visited area. Next, players explore nine locations along the Lehigh River. Each location has two or three photospheres (i.e., immersive 360° photos). To keep advancing in this linear point-and-click, narrative-based DGLE (Squire & Klopfer, 2007), players need to explore every photosphere completely by collecting the historical photos, watching videos, and reading the local information signs by clicking on these resources' respective icons (see Figure 3). Before moving forward to the next location, players answer one multiple choice question to summarize the main aspect of that area.

After exploring the last location in the river confluence, players return to the D&L to report on their findings. Players achieve their main goal by recommending three locations to receive improvements that would increase tourism and community engagement along the Lehigh River. Upon game completion, the D&L game avatars award players with the title of “Watershed Explorer”.

Figure 2. *Flyover images.*



Note. Students are introduced to the Lehigh River watershed (left), ending up at the first location, the Francis E. Walter dam (right).

Figure 3. *Image of the Francis E. Walter photosphere.*



Prototype Implementation

In Summer 2021, the initial prototype version was implemented with 35 students ages 10-14. The students completed a pretest-posttest content assessment measuring watershed literacy, a motivation to play with a dVR game survey, and a perception of learning with dVR games survey. Results showed that using *Watershed Explorers* as a curriculum enhancement activity can positively impact learning, especially middle school students' ability to identify their own local watershed and its connections to the ocean. The majority of students perceived *Watershed Explorers* as a helpful and engaging type of learning technology that can promote stimulating ways of presenting content materials and make school learning more interesting (for more details see Araujo-Junior & Bodzin, 2022).

One of the main issues that occurred during the prototype implementation was that many students took over 50 minutes to complete *Watershed Explorers*. To address this, we conducted a usability study with our preservice and inservice teachers who were enrolled in our institution's secondary science methods course and our Environmental Education course during the Spring 2022 semester. The university students completed *Watershed Explorers* and were asked to think of related themes for a shorter version of the DGLE that would have only 3 locations instead of 9 locations. They also completed a usability survey that focused on the usefulness of the DGLE's supportive features that included the game tutorial, journal log, media gallery, glossary, tool tips, conversation logs, and location panels. The students also responded to a survey about specific game features and their perceptions of learning with the DGLE.

The students proposed four different thematic 3-location versions of *Watershed Explorers*. The *fish ladder theme* includes three locations with a fish ladder placed adjacent to a dam to assist with the shad migration up the river for spawning; the *environmental issues theme* focuses on locations with pollution issues that include an abandoned mine drainage stream, a brownfield development site on a former steel plant, and a Superfund site that was denuded from a zinc smelting operation and is currently undergoing revegetation; an *industrial history theme*, and a *general history theme*. The students reported that the game narrative was clear and made sense, they discovered things about the watershed that they previously did not know, they liked using the DGLE for learning about the watershed, they found the game and its interface easy to use, and they did not feel overwhelmed by the amount of information that was presented. They found the DGLE's supportive features useful but did not revisit them after they were first introduced. They recommended that after visiting the second location, the game should prompt the player to open the journal log, media gallery, and conversation logs and also remind the

player to use the glossary. Based on our students' feedback, we are revising the DGLE and developing four shorter versions for teachers to use with their students. In addition, we have developed a curriculum supplement with additional curriculum integration ideas and assessment materials to assist teachers with using *Watershed Explorers* in classrooms.

Implications for Science Teacher Educators

Many institutions are located in or near watersheds that have past and/or current environmental issues. Understanding and addressing environmental issues is important for promoting environmental literacy and for preparing science teachers. Thus, *Watershed Explorers* has broad appeal to science teacher educators living in other geographical locations.

Many areas have non-formal environmental education or STEM-related centers that look to partner with higher education faculty to promote environmental and watershed literacy to the public. These centers are an invaluable resource that can provide science teacher educators with environmental content expertise, rich visual imagery, and other resources that could be used to enhance the development of a personalized DGLE. The *Watershed Explorers* DGLE was created through a collaborative partnership between faculty at our institution and our EE partners. This collaboration resulted in a superior learning experience that would likely have not been as successful with our inservice and preservice science teachers had either partner developed the DGLE on their own.

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