How Healthy Are Our Streams and River? - Initial Headset VR Prototype Functionality with GIS

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Abstract. *How Healthy Are Our Streams and Rivers* is a GIS-based immersive learning experience using virtual reality (VR) to explore water quality in the Lehigh River watershed. This project enables learners to analyze water quality data through interactive virtual macroinvertebrate surveys at four distinct tributary locations. The game is designed to enhance spatial understandings of the watershed while promoting environmental literacy by incorporating GIS capabilities within the Unity 3D real-time development game engine. Players assess water quality health with virtual macroinvertebrate surveys, examine anthropogenic impacts, and explore remediation strategies. The project uses the ArcGIS SDK for players to interact with offline geospatial data layers in a VR environment, while overcoming challenges such as limited network connectivity common in non-formal education settings. We present our initial prototype development with a primary focus on the GIS functionality within the Unity environment. This iLEAD paper describes the learning experiences and its conceptual understandings, and our initially developed GIS functionalities for immersive learning with a water quality investigation in a Unity-developed headset VR environment.

Keywords: GIS, ArcGIS SDK, Water quality, Headset VR design.

1 Introduction

How Healthy Are Our Stream and Rivers is a Geographical Information Systems (GIS)-based learning experience for headset virtual reality (VR) that is designed for learners to investigate the water quality at four tributaries in the Lehigh River watershed. It is developed using a design partnership with the PA Department of Conservation and Natural Resources - Jacobsburg Environmental Education Center for non-formal education use in environmental science education and related centers in the watershed for learners of all ages. GIS is a dynamic mapping application that is used for managing and analyzing spatial and geographic data, enabling users to visualize, interpret, and understand data patterns and relationships in a geographic context. An important goal of this project is to promote important spatial understandings of the watershed in which players will investigate spatial patterns and relationships among georeferenced data to understand how water quality is impacted at different locations in the watershed. Since immersive headset VR experiences have been found to promote interest, enjoyment, and learning in non-formal education settings [1], we have focused our design and development for this hardware.

GIS have proven to be a valuable tool in the process of understanding the environment and of making responsible environmental decisions [2]. It can be used to develop critical thinking and data analysis skills when applied to authentic contexts. GIS use for learning activities can cross disciplinary boundaries by integrating data from both natural and social sciences. When learners engage in inquiry-based investigations using GIS data and visualizations, they engage in scientific practices, utilizing evidence as scientists do [3]. Furthermore, GIS can be appropriately used for activities that promote independent learning and geospatial reasoning [4]. When appropriately designed, an immersive GIS environment may offer an excellent platform for managing, organizing and presenting authentic spatial data to investigate real-world problems.

In 2020, Esri announced a Beta program for integrating ArcGIS with real-time development engines, also referred to as game engines [5]. This involves using an ArcGIS Maps SDK for Unity to enable XR developers to integrate spatial data into immersive VR environments. Initial work with ArcGIS integration with game engines has appeared in the literature for developing geo-visualizations for forestry education [6], recreating a 3D visualization of a large-scale landscape of the historic pre-dam Vlatava River valley [7], and including GIS mapping layers into the virtual archeology Angkor project [8]. Integrating GIS data into Unity for non-formal educational settings, such as public outreach, presents several challenges. The ArcGIS Maps SDK typically requires internet connectivity to access geo-referenced data from hosting networks. Thus online connectivity is essential for displaying information when selecting a data layer in a VR environment. Our partner environmental education center has Internet access with firewalls that restricts data access to host networks. Therefore, we needed to create a work-around solution for VR headset users to access georeferenced data information in Unity.

In this paper, we describe our initial prototype development of *How Healthy Are Our Stream and Rivers* with a primary focus on the GIS functionality within the Unity environment. We present an overview of the learning experience and its conceptual understandings, our initial GIS functionalities, and our initial design and development for the water quality investigation in a Unity-developed headset VR environment.

2 Game Overview

How Healthy Are Our Stream and Rivers is an immersive game in which players will visit four distinct locations in the Lehigh River watershed and the adjacent Bushkill Creek watershed to assess the water quality at each location with a virtual macroinvertebrate survey. Macroinvertebrate surveys are widely used as indicators of water quality because these organisms are sensitive to environmental changes and pollution levels. Different species have varying levels of tolerance to pollutants. The presence or absence of certain indicator species helps determine water quality. For example, mayflies, stoneflies, and caddisflies are sensitive to pollution, so their abundance indicates good water quality.

The storyline of the game introduces an angler stakeholder who is looking for healthy water quality in the streams and river for their recreation purposes. The player is tasked to assist the angler by visiting four distinct locations and assessing the health of the water. The locations include an abandoned mine drainage impacted stream, a farm-adjacent stream, a stream with primary source pollution from an urban area, and a less disturbed location within a state park. The player collects biological data using a virtual macroinvertebrate survey. During the learning activities, the player analyzes their data to determine the stream health, identifies spatial data patterns in the watershed related to the water quality at each location, and examines environmental impacts. To promote healthy streams in these locations, the player is presented with various community solutions that include creating riparian buffers, removing dams, protecting critical areas in headwaters, and mitigating mine drainage streams. Results and motivational feedback are provided after each choice is made. Remediation choices are weighted for different levels of impact, as solutions on multiple tributaries are required to promote a healthy watershed.

As noted previously, the game is being developed for non-formal educational settings. The conceptual understandings for the learning experience include:

- The Lehigh River and its tributaries are used for a variety of purposes. These include recreation uses, habitat for aquatic organisms, and provides drinking water to area municipalities.
- Macroinvertebrates are an indicator of the health of a river or stream.
- Anthropogenic factors affecting water quality include impacts due to agriculture (e.g., use of fertilizers, manures and pesticides, animal husbandry activities), pollution due to industrial effluents and domestic sewage, mining, urban development, and recreational activities.
- Poor water quality in rivers and streams can be remediated in various ways. These include creating riparian buffers for agricultural and mitigating mine drainage streams, removing old dams, and protecting critical areas in headwaters.
- Personal habits one can do to prevent water pollution. These include picking up litter and recycling it or throw it away in a trash can, not having the perfect green lawn by using fertilizers that wash in the stream, having natural backyard habitat instead of a manicured lawn, planting native plants and shrubs when a tree needs to be removed for erosion reduction, preventing nutrient pollution, reducing heat

island effect, washing cars or outdoor equipment in grassy or gravel area to prevent runoff into storm drains, and not disposing of oil or other harmful substances in storm drains.
- Stormwater runoff drains directly into a river without any treatment. As it travels to the storm sewer system the runoff picks up debris, chemicals, dirt and other pollutants and carries them straight into our rivers, lakes and streams.
- Our communities can take action to enhance water quality. These include removing dams to assist with fish migration and removing silt clogs in the river that impair spawning and feeding.
- Riparian (vegetated) buffers are important and a provide for a natural solution for stream health. They include a wide area of native plants and grass along a stream or river. This reduces stream erosion and restores habitat for spawning. As a result, run-off pollution from excess fertilizers and pesticides is reduced, resulting in a cleaner water supply. Intact buffers also reduce flood frequency, severity and associated property damage. Vegetated stream banks provide food and shelter for birds, butterflies, small mammals and other wildlife. A forested buffer is the best possible buffer for stream health.

3 Initial GIS Functionality Development

Developing an immersive GIS environment for this spatial learning experience involved exploring different GIS data displays to assist with making geospatial patterns and relationships readily apparent to players. To assist players with understanding the spatial nature of the watershed, careful planning with regards to how the player would navigate and move in the VR headset had to be considered. Data display functionality had to be created for players to be able to turn on and off data layers, view a legend to interpret the map displays, and consider how players would interpret macro views of the watershed in addition to detailed micro views at specific locations.

The data layers displayed in the VR GIS watershed map (see Fig. 1) includes the Lehigh River and Bushkill Creek watershed boundaries, cities/towns, land use, the Lehigh River, tributaries/streams, and coal mines. This initial visualization highlights the relationship of cities and towns that have been developed along the Lehigh River (see black dots). The land use colors indicate developed areas (red color), agricultural (yellow color), and forested areas (green color) in the watershed.

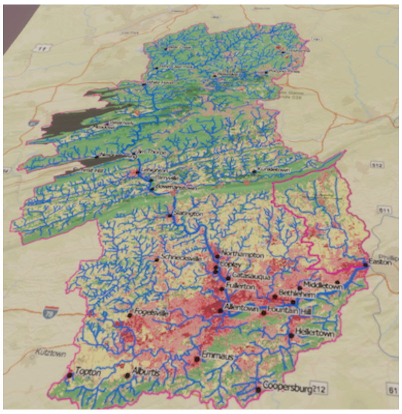

Fig. 1. The GIS watershed map displayed in Unity. Red color denotes developed areas, green color denotes forested areas, and yellow color denotes agricultural areas. Black color represents coal mines. Blue color represents the Lehigh River, streams and tributaries.

Our main development challenge was to employ a process for the player to access geospatial data from the data layers without a live internet connection. This involved using ArcGIS Pro to create a vector tile package (.vtpk file) from a vector layer tile service. The .vtpk file is then imported into Unity using an API key with associated coding for the ArcGIS basemap and the vector tile layers.

Pressing the “A” button on the right VR headset controller displays the data layers that the player can toggle on and off in the map visualization (see Fig. 2). The location layer is selected when the player aims the raycaster (i.e., virtual pointer) at the GIS map and presses the right trigger button. Then, a red sphere marks the selected position along with a pop-up screen displays the location name and any other embedded spatial data or information (Fig. 3). Place names for the sampling sites are also displayed on the map to help the player understand the geographical distances among the different sampling locations.

4 The Macroinvertebrate Survey

We conceptualized a simulated macoinvertebrate survey in which a player would have to pick up a net near a stream, walk into the stream, and kick-up some rocks so that the macroinvertebrates could be captured with the net. The player would then take the net out of the stream and place its content into a stream table to examine and classify the macroinvertebrates. The species would self-sort into a display of ‘tolerant’, ‘somewhat sensitive’, and ‘sensitive’ macroinvertebrates that would be used for the player to assess the overall health of the stream at that specific location. Each location would have different species diversity. For example, the Jacobsburg site on the Bushkill Creek would have the best water quality with the most species diversity and the most sensitive types of macroinvertebrate indicator species. The Buck Mountain Creek at Rockport, an abandoned mine drainage stream, would have the lowest species diversity and number of individuals and would not contain sensitive macroinvertebrate species and would have the most tolerant water quality indicator species. The Catasauqua Creek located downstream from some agricultural areas and the Lehigh River in Bethlehem would have an intermediate species diversity.

Fig. 2. The data layer toggles and legend within the Unity environment.

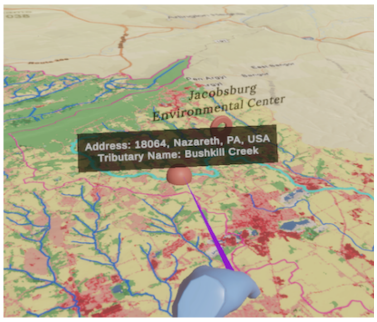

Fig. 3. Raycaster functionality to display embedded location data. Note that the Jacobsburg sampling site location is also displayed on the map.

We have developed an initial prototype location to represent the Jacobsburg sampling site (see Fig. 4). At the site, the player can use the VR controller to pick up a net and walk into the Bushkill Creek. A brief cutscene is used to simulate the motion of kicking the rocks in the stream to capture the macroinvertebrates in the net. The net is brought to the stream table on the stream bank to identify the macroinvertebrates.

Fig. 4. The immersive Jacobsburg VR sampling site in Unity. The UI panel for the macroinvertebrate visualization (top). The stream table with survey equipment including plastic tray and net (bottom).

5 Next Steps

As previously discussed, the work to date has focused primarily on developing initial GIS functionalities within the Unity environment for the headset VR learning experience. The next steps in our ongoing development process includes designing and testing the UI (user interface) for the geospatial data interfaces and visualizations. This includes designing and testing the GIS map data layer order map displays, legend colors, and map symbols used to represent different types of data or features to facilitate users with understanding the displayed geospatial information. In addition, we have begun designing and testing the ease of use with the headset controllers for movement and navigating within the GIS Unity environment and using the raycasters for displaying georeferenced data on the map while considering ease of use for players, many who are likely to be first time VR headset users. These design and development steps are important to ensure that the interfaces are user-friendly for a wide age range and to ensure that users do not experience motion sickness while navigating in the GIS-based VR environment. The next steps in the work flow will also focus on the continued development of the game tutorial from our storyboard and developing the other three sampling sites.

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