Virtual Reality: Authentic and Immersive Learning in the Science Classroom

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Abstract
The diversity of learners within education is neither linear nor constant. Educators are challenged to be responsive and understanding when encouraging learners to construct meaning while adhering to stringent standards. The objective of this study is to integrate science standards into authentic learning experiences, created in both a traditional teaching method and virtual reality (VR) platform, for 8th grade middle school students in Lafayette, Louisiana. The authentic experiences were based on oral histories of the residents of Isle de Jean Charles, Louisiana, who have lost 98% of their ancestral homeland since 1955. These experiences were then tied to the National Science Standards (8-MS-ESS1-4, 8-MS-ESS2-2, and 8-MS-ESS3-1). The students were split into two groups and given either a PowerPoint or VR experience, both having the same content. The researchers tracked engagement, focus, interest, and how important the students thought the content was. Using an experimental approach, the researchers also gave a pre- and posttest to determine if the VR experience resulted in better academic learning than a regular, PowerPoint-based lecture. The students were also asked to comment on their experience of the PowerPoint versus the VR and describe their experience. As shown in the results of the study the students who completed the PPT experience ***agreed*** it was engaging, but those who completed the VR found the experience ***strongly agreed*** that it was engaging. When the students were asked about the experiences helping with focus the students ***agreed*** that it did help them, but those who were tested with the VR ***strongly agreed*** that it helped with focus.

1. Introduction
Few approaches offer the potential benefits of VR learning technology. Though the design and implementation of immersive learning experiences is closely tied to curriculum standards, there is an opportunity to speed up the learning process and simultaneously measure student progress. The overarching goal of this project is to enhance the quality of research and education in experiential learning about sustainability by using 360-degree videography to capture oral history and present this in a VR platform.
According to *U.S. News & World Report*, Louisiana currently ranks 49th among the 50 states in terms of education. There is a myriad of efforts that are underway to address students' deficiencies in Louisiana's public-school systems. The use of VR and serious gaming for education has been shown, under certain circumstances, to allow for more efficient learning and cognitive material intake [1],[2]. It has been statistically shown that students are more motivated by game-based learning and that this has a significant impact on their learning achievement [3]. Serious game tasks can promote 21st century problem-solving skills and knowledge of concepts [4]. Interaction with a 3D environment in VR is powerful for both static and dynamic information, and some of the most well-engineered and commercially successful applications for direct-manipulation interfaces are video games [5]. Using knowledge tests, immersive serious games have been shown to captivate students more than traditional methods, leading to superior retention [6]. The results from this research corroborate these results and show that more testing is needed to determine how

and when to VR should be implemented in the K–12 classroom.

Authentic learning, such as that focused on sustainability has a global interest, but it is especially critical in Louisiana as the state lies only 100 feet above sea level. Too, one-quarter of Louisiana's land is in the Mississippi delta, where one-third of it is covered by fresh- and saltwater wetlands. The content for this lesson focused on Isle de Jean Charles, the ancestral home of the Isle de Jean Charles Band of Biloxi-Chitimacha-Choctaw Indians. The tribe is recognized as the first climate refugees in the contiguous United States. They want to share their experiences in order to prevent future communities from losing their homes. The lessons were created using archival research about the Island and include simulations and 360-degree video of the Island. The resources listed above are integrated into the application and presented in VR headsets.

1.1. Overview of the Literature

Until recently, the use of VR in the schools has been cost-prohibitive. The use of immersive VR environments in order for students to experience authentic and realistic virtual scenes is becoming more and more possible [7]. Virtual environments allow for the blending of real places with virtual content. As an educational tool, immersive environments allow students to reach places not easily accessible from within the classroom setting, creating learning interactions within the virtual environment [8]. This is integrated into the current curriculum standards [9]. Additionally, VR is preferred by educators over traditional learning tools [10] as, specifically, the opportunity to develop immersive learning experiences. Teachers found VR beneficial in teaching complicated concepts [11],[12]. Recent developments found that VR paired with immersive experiences can significantly help in learning complicated scientific concepts [13]. Other studies found strong evidence that enhancing interactive (e.g., allowing users to interact with the environment) and immersive components (i.e., allowing users to immerse in the virtual world) in VR can increase engagement of learners in educational settings [14].

Another benefit of applying VR in an educational setting is that it can immerse students in an interactive educational environment that is too expensive to create [15]. Although some scientific concepts are visible (e.g., a chemical reaction that has change in colors), many are not observable in the real world (e.g., planets). Even if it is observable, it may be too expensive for some schools (e.g., a field trip to understand a specific ecology). This is particularly problematic for low-performing students who often come from lower socioeconomic status.

1.2. Project Goals and Research Questions

The goals of this project are to design and implement an immersive learning experience using VR for middle school science teachers to teach topics relating to sustainability. To assess the effectiveness of the pedagogy, an experimental design was used to test whether students who learned the materials using VR had better outcomes than students who learned with a traditional PowerPoint (PPT) lecture. Specifically, our research questions asked, when compared with the PPT lecture condition, if students in the VR condition:

1. have a higher quiz score of knowledge after the lesson?
2. show higher academic motivation to science and school after the lesson?
3. show higher engagement in learning science after the lesson?
4. show a more positive sentiment about the lesson?

2. Lesson Design and Method

2.1. Sample and Procedure

The study used both quantitative and qualitative methods to gauge the students' experience. The VR and PPT experience both took between 15–20 minutes to complete. There was a check for understanding in both the VR and the PPT experiences. The content of the VR and PPT were completely the same.

There were five sessions of classes that were taught the same topic. These sessions were taught via the VR condition or through traditional PPT slide. Because of the unequal number of students in each session, we had more students in the VR than in the PPT slides group. Students completed a pretest a week before the lesson and a posttest right after the lesson.

Our sample consisted of 116 8th graders who completed both the pretest, posttest, and the lesson (PPT vs. VR). Among them, 68 were female and 48 were male; 70 were in the VR condition and 46 were in the PPT slide condition. Students in the VR condition were not significantly different from students in the PPT slide condition in their pretest quiz score or pretest academic motivation score. This showed that the samples in the two conditions were not different.

2.2. Planning

In planning the lesson design, the researcher worked with the classroom teacher to determine what lesson would align with both the classroom lessons and the curriculum for the district. Researcher Stone had been working with the Biloxi-Chitimacha-Choctaw tribe from Isle de Jean Charles (IDJC) and wanted to tie in the tribe's experiences with land loss to the standards 8th grade students were learning in their classroom. The essential questions from the Lafayette Parish School System curriculum that would be answered based on the lesson were as follows:

1. Why is Louisiana such a fragile region?
2. How does the land loss in Louisiana affect the natural resources?
3. What are the human factors that impact land loss in Louisiana?

These essential questions tie into the Next Generation Science Standards. The specific standards, which are all 8th grade standards in the category of Earth Science, are as follows:

- 8-MS-ESS1-4: Earth's Place in the Universe
- 8-MS-ESS2-2: Earth's Systems
- 8-MS-ESS3-1: Earth and Human Activity

Once the determination had been made on which standard the experiences would teach, the researcher and the teacher worked together to determine a set of multiple-choice questions to test the knowledge that the students needed to know. Below are some of these questions:

- What long-term effect did the loss of marshland have on local animals?
- How were the residents of the Island economically affected by land loss?
- How was the bayou cut off from fresh water?
- How have the changes on IDJC impacted its people?

Researcher Stone then reviewed the 360-degree videos of oral histories collected from tribal members living on the Island and chose specific segments that would demonstrate the key concepts chosen for the lesson. A script was created to supplement the narrator's stories and explain the background of how the land loss was affecting IDJC.

The same script was used for both the VR and the PPT versions of the lesson. There are four scenes with follow-up questions that are a check for understanding. The first sets the stage and shows the students where IDJC is in relation to the world. The next shows a backwards model of what IDJC looks like in 2016 versus what it looked like in 1963. The narrator points out the difference in the marshland surrounding the Island in 1963 and the water in 2016. The next three scenes feature videos of IDJC Tribal members, starting with Wenceslaus Billiot, then moving on to Maryline Naquin, and finishing up with Father Roch Naquin.

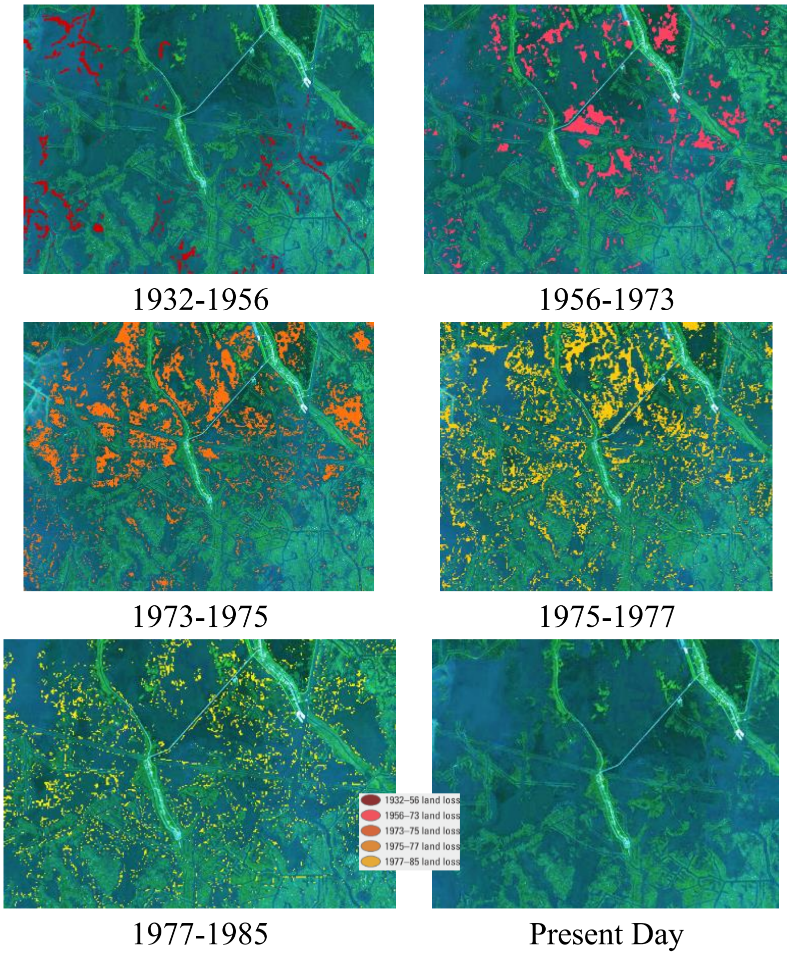

Figure 1. Changes on Isle de Jean Charles from 1932–1985.

2.3. *Differences in Virtual Reality and PowerPoint Versions*

In the VR version, the students were shown a world map that zoomed in slowly to the U.S., Louisiana, and then finally IDJC. Throughout the process, each area is highlighted. The PPT version begins with a picture of the world that then zoomed to IDJC, using Google Earth (see Figure 1). During this, the narration below was presented to students.

Narrator:

The Mississippi delta region was slowly created by the Mississippi River over the last 8,000 years. Over the last 300 years, humans have significantly altered its natural path and disrupted its flow. The river flow has been forced on new paths to the Gulf and fresh water is not being distributed to all areas of the Mississippi delta; Isle de Jean Charles, Louisiana, in Terrebonne Parish is one such area.

The depletion of natural resources in the coastal region of Louisiana was first seen in the early 1800s with the beginning of the exhaustion of hardwoods due to logging and the levee system. These forests were for materials in building homes and other construction. The trees also prevented the erosion of soil, which helped maintain the marsh.

Louisiana's 3.5 million acres of coastal wetlands have been condemned as suffering the fastest land loss on the continent. The damage to the ecosystem changed the land and with it the lives of those there first. Louisiana is predicted to lose 1,750 square miles of land in the next 50 years if no action is taken.

In the creation of the VR lesson, 360-degree videos are integrated into the virtual environment. This allows the students to look around the home of the narrator and be immersed in the experience (see Figure 2,3). In the PPT lessons, the 360-degree videos are flattened into a typical video one would see embedded in a PPT presentation (e.g., MP4).

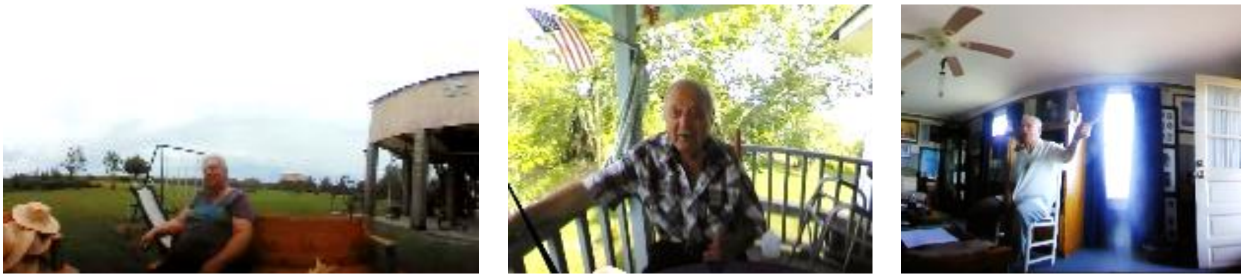

Figure 2. Images from 360-degree videos: left, Maryline Naquin; middle, Wenceslaus Billiot; right, Father Roch Naquin.

Figure 3. Images from PowerPoint presentation left, Maryline Naquin; middle, Wenceslaus Billiot; right, Father Roch Naquin.

The check for understandings was built into the VR environment with the student using the remote from the Oculus Go (Facebook, California) to answer (see Figure 4). If the student gets the answer correct, then the narrator says, "Correct," and proceeds to tell them why. If the student answers incorrectly, then the narrator says, "Not exactly," and proceeds to explain why they did not get the answer correct. The student must click on the correct answer to move on to the next scene. In the PPT version, the answers are displayed on the PPT slide, which the teacher reads to the whole class; the students answer as a group. The teacher then reads both what would happen if the student got the answer wrong and if they answered correctly.

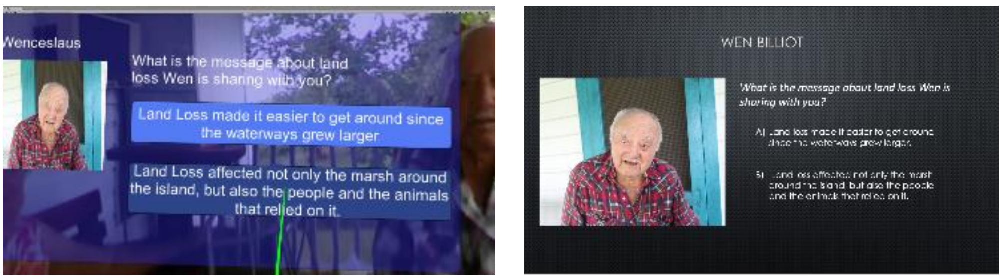

Figure 4. Images of check for understanding left, in virtual reality; right, in PowerPoint presentation.

The final scene for the PPT ends with the check for understanding on the information that Maryline Naquin shared. There is a bonus scene in the VR version. The student is immersed in a submersible and the effect of erosion is coming at the window in a 3D effect. While this is occurring, the screen on the submersible shows the land loss from 1963 to the current on IDJC. This was not possible to do in the PPT version as it was modeled in the VR environment.

2.4. Assessment Measures

To assess whether students in the VR condition had better learning outcomes than students in the lecture condition, several learning outcomes were measured before and after students learned the materials. Specifically, we measured students' knowledge of the content and academic motivation a week before the lesson and immediately after the lesson. We also measured students' attitudes toward the lesson after the lesson. To assess students' knowledge, ten quiz questions were developed by the classroom teacher and the educational researcher. In addition to knowledge, academic motivation was rated from 1 (strongly disagree) to 5 (strongly agree) and measured using a modified version of an academic motivation scale previously tested in the same population, tapping into students' interests in school, science, and the class topic. Attitudes toward the lesson were measured using a 9-item Likert scale measuring students' engagement in the lesson (VR vs. PPT lecture) (see Figure 5,6).

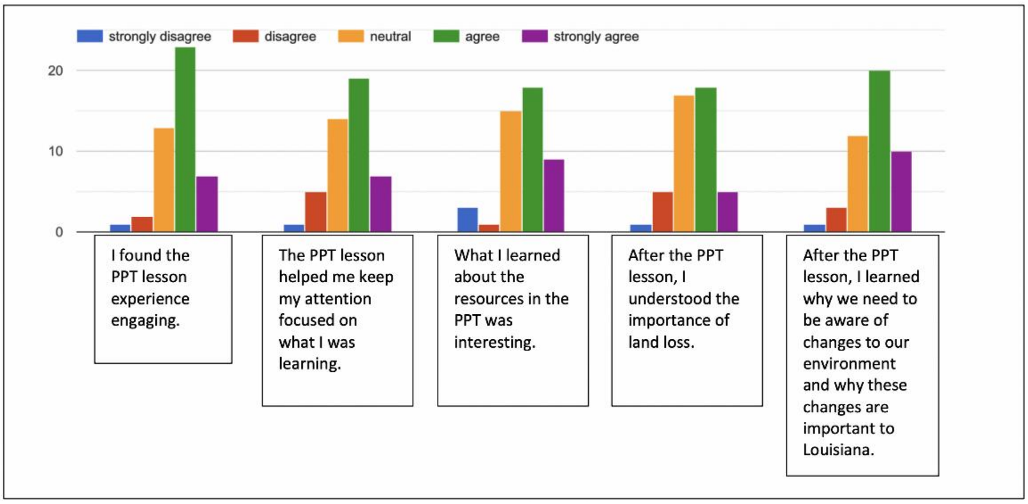

Figure 5. Results from the PowerPoint (PPT) presentation lesson.

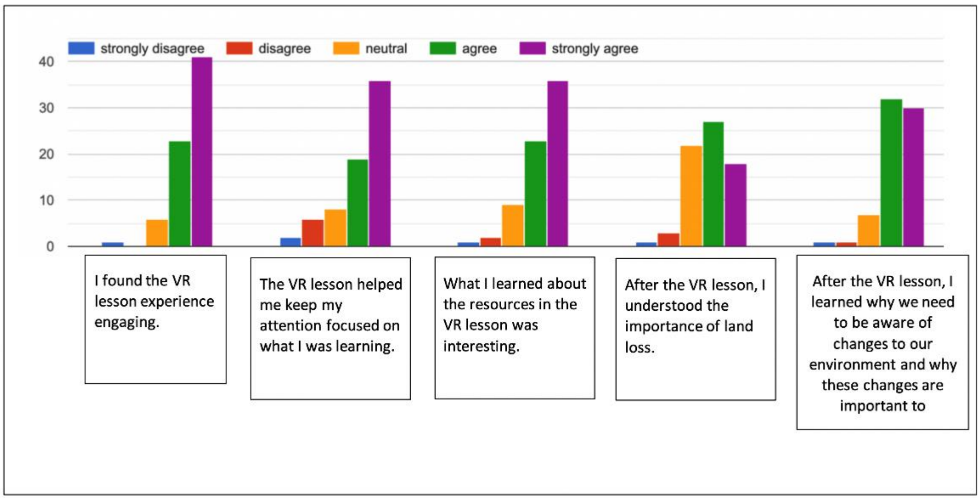

Figure 6. Results from virtual reality (VR) immersion lesson.

Finally, students were asked to write freely their feelings and thoughts of the lesson. Text mining strategy was then used to compute students' sentiments as reflected in their written responses. Specifically, R package sentiment [16] was used to extract sentiment scores from students' written responses.

To assess students' learning outcomes across conditions, a series of nonparametric Wilcoxon rank sum tests was performed using R programming. Wilcoxon rank sum tests were chosen because our sample is small, and the two conditions have unequal sizes.

2.5.Application Development

To develop the application, 360-degree videos were taken on location. The videos and 3D models were then brought into the Unity 3D game engine [17], where interactive educational content is added. The 360-degree videography used for content creation was filmed using three 360-degree cameras: the 360 Fly, which has a single fish-eye lens, the YI 360, which had dual fish-eye lens, and the Panotek camera rig, which uses ten YI 4K cameras. The Panotek camera rig requires postprocessing in the form of stitching and editing to correctly align all the videos. The Kolor software, (GoPro, California) Autopano Video Pro [18], and Autopano Giga [19], are used to stich and edit the videos. Audio is recorded and edited using the digital audio editor, Audacity [20]. Blender [21] and Maya [22] are used for 3D modeling of objects in the scene and applying textures. The Unity 3D plugin iTween [23] provides an animation system that was used to control the vehicle and player locomotion, and the plugin, VRTK (VR tool kit) [24], provided grabbing interactions and controls. All of the programming was done using C# in Visual Studio [25] for the Unity 3D game engine. The Oculus Go VR headset is used for display and interaction.

3. Results/Assessment

3.1.Statistical Findings

Paired sample Wilcoxon rank sum tests were performed to test, across the two conditions, whether students' quiz scores and academic motivation were improved after the lesson. Results of the statistical tests revealed that students showed improvement in the quiz scores in both VR condition ($W = 269.5$, $P < 0.001$) and PPT slide condition ($W = 65$, $P < 0.001$) (see Figure 7).

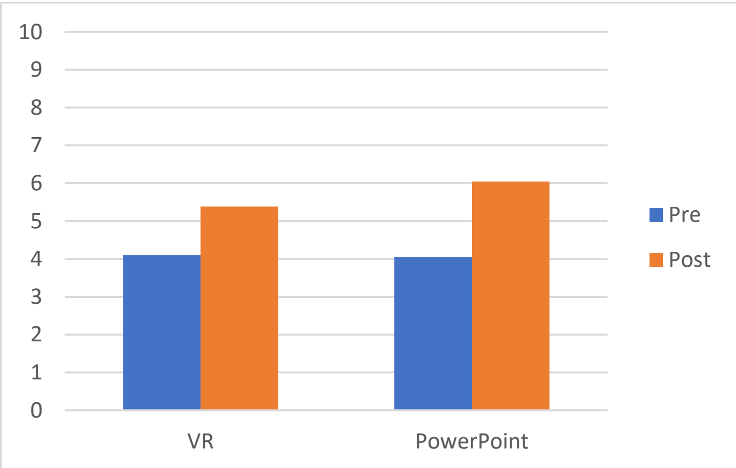

Figure 7. Quiz scores across conditions.

In addition to quiz scores, our results showed that students in the VR condition showed significantly more improvement in academic motivation than had students in the PPT slide condition ($W = 3592.5$, $P < 0.001$). Specifically, compared with baseline measure, students in VR condition reported higher academic motivation ($W = 422.5$, $P = 0.006$). However, students in the PPT lecture showed no significant improvement in academic motivation ($W = 144.5$, $P = 0.184$) (see Figure 8).

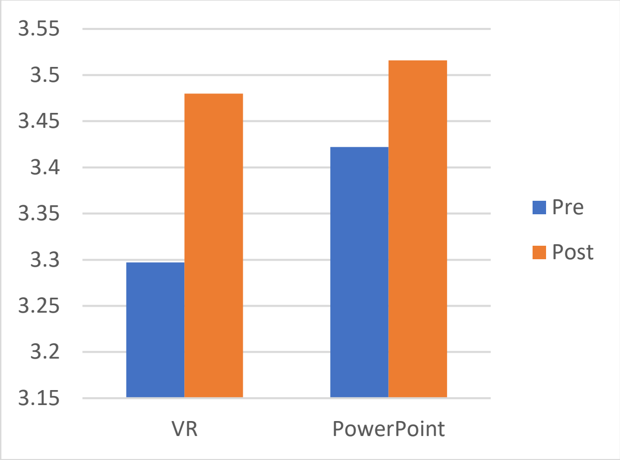

Figure 8. Academic motivation across conditions.

Overall, students in the VR condition reported feeling more engaged (i.e., had a more positive attitude toward the lesson) (W = 13225, $P < 0.001$) and showed more positive sentiments in their lesson feedback (W = 4005, $P < 0.001$) than students in the PPT slide condition.

In summary, although both conditions showed improved knowledge toward the learning materials (i.e., both the VR and the PPT conditions are useful in improving students' knowledge), students that were taught with the VR condition showed greater improvement in academic motivation (i.e., interests in school, science, and the class), more positive attitudes toward the lesson, and more positive sentiments toward the lesson than students who were taught with the traditional PPT lesson (see Figure 9,10).

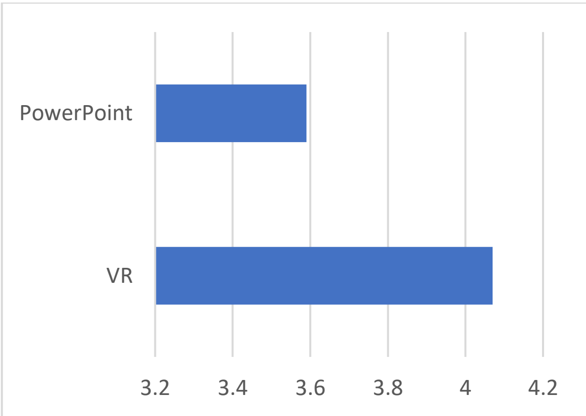

Figure 9. Lesson engagement.

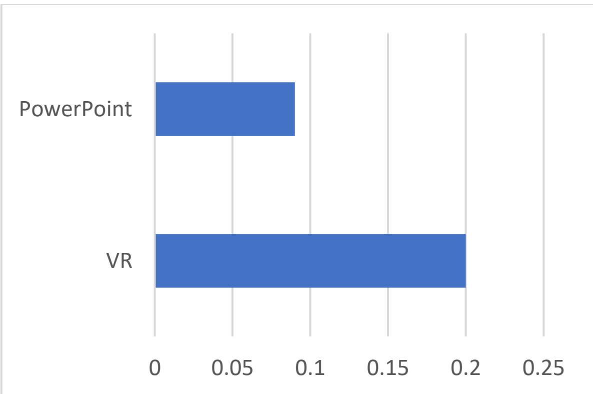

Figure 10. Positive emotion experienced.

3.2.Students' Feedback for the Virtual Reality Experience

Students' feedback was in general positive about the VR experience. Our sentiment analysis showed that for participants in the VR condition, 85.7% of the students expressed positive emotion after the lesson, while only 62.2% of the students in the PPT condition expressed positive emotion. Some students expressed that being able to use VR to view the actual environment helped them understand the materials and visualize science.

- *"It is like you are right there with them—they are talking to and with you. I liked it and [am] glad I got to experience it."*
- *"…my virtual reality experience was amazing.… This VR showed me different things and how awesome it is to pay attention to actual science."*
- *"I've had fun seeing stuff like I was really there on the VR. I've learned about how people use to love fishing and getting on their boats in the water and the VR made it so much more real."*

Students also expressed that they would like more VR experiences in the future.

- *"The virtual reality was really cool, and I think that if we did it more often that it would really help us with the lessons."*
- *"…VR was a really fun way to learn [ring levee] and I think we should use this in school like how we use the chrome books."*

Other students reported how VR helped them focus when learning.

- *"It was great, it helped me stay on task and it helped me learn about the subject faster."*

3.3.Students' Feedback for the PowerPoint Experience

Students' feedback showed they related to the IDJC residents through the PPT experience. The students were interested in the content and felt like they learned from a story to which they could relate.

- *"I learned about the land loss and the climate troubles and the people who were affected by the loss of the land."*
- *"The PowerPoint lesson was interesting. I like the fact they got people from the community [got] to show their perspective. It showed me how bad land loss is and makes me interested on the topic of trying to stop it."*
- *"The PowerPoint was nice and interesting. I learned why the people of the island cannot go fishing and have barely any trees. I liked the videos and how the globe zoomed into the island."*

None of the students said they wished for more PPT experiences in the future nor did they give any mention of how the PPT focused or increased their understanding.

4. Summary/Conclusion

As shown in the results of the study the students who completed the PPT experience ***agreed*** it was engaging, but those who completed the VR found the experience ***strongly agreed*** that it was engaging. When the students were asked about the experiences helping with focus the students ***agreed*** that it did help them, but those who were tested with the VR ***strongly agreed*** that it helped with focus. As for the Wilcoxon rank sum indices, the results showed that higher improvement with the VR versus the PPT between the pre- and posttests. When the students were asked to comment on the experiences, the typical response for the PPT was about how they enjoyed the content; however, for the VR, this comment sums them up, "My experience with virtual reality was incredible. I really like it. It was something new and something different for me." The analysis of this project shows that students were not only more engaged and focused with the VR experience, but that they improved academically.

5. Recommendations for Future Educational Virtual Reality Applications

- Create interactive lessons where students can engage with the content in VR.
- Discover other communities to tell their stories in a VR experience that will support other curriculum standards.
- Support students research on communities undergoing change that would support learning standards.
- Create a platform where students can help build the VR experiences.
- Assess students' long-term retention by retesting a month after the experience.

6. Acknowledgments

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