Multi-Party Mixed Reality Interaction for Earth Sciences Education

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ABSTRACT

Collaborative learning has been shown to be beneficial for children's learning performance, increasing the curiosity and intensity of the ability of cooperation. Mixed-Reality with collaborative learning is the trending research topic in the Human-Computer Interaction (HCI) area. Additionally, with the rise of attention to global warming which brings in more extreme weather and climate conditions, the earth science education would be one of the crucial topics for the next generation. Moreover, there are few augmented reality and mixed reality applications on earth science subject. In this paper, we propose a Mixed Reality Tornado Simulator which offers an earth science education in a collaborative setting. Students and the instructor can cooperate on learning the knowledge of the formation and its damage cause on human-built structures, farming, and vegetation by using our mixed reality application with the Microsoft HoloLens. Also, for evaluating the learning performance in this mixed reality setting, we propose to study the cognitive load while the student is learning the abstract knowledge in Earth Science. We will separate the student into a control group and experimental groups and use different teaching instruments to test the difference of cognitive load.

CCS Concepts

•Human-centered computing → Mixed / augmented reality; •Applied computing → Computer-assisted instruction; Interactive learning environments; Collaborative learning;

Author Keywords

Mixed Reality, Interactive Earth Sciences Education, Microsoft HoloLens, Collaborative Learning

INTRODUCTION

From the climate data in National Aeronautics and Space Administration (NASA) [10], global temperatures have risen about 1.62 degrees Fahrenheit since the late 19th century, sea level increases 3.2 millimeters per year, Arctic ice decrease by 12.8 percent per decade and the extreme weather events happen more often since the 19th century. NASA also predicted that the hurricanes, also known as typhoons, will become frequent and stronger, sea level will rise 1-4 feet by 2020 and the Arctic likely to become ice-free before mid-21st-century [10].

With these concerns in mind, it is crucial for the human being to work together to make the global climate change speed become slower. One immediate step is to raise the awareness about climate change with the education of our students in K12 earth science classes. In the United States, middle and high school teachers teach earth and space science (ESS) which is included in the new Next Generation Science Standards (NGSS) for K-12 science education [5]. In ESS [1] disciplinary core ideas including earth's place in the universe, earth's system and earth and human activity. Students will learn the knowledge of earth science from primary school (K-2) to high school (9 - 12 grades) which is sufficient enough to cultivate the earth science knowledge. With the development of advanced immersive technologies, the class material could go beyond the textbook and the videos. Research shows that students learn more efficiently when the instructor uses technology instruments in class and deploys interactive learning activity along with the class materials [12, 14]. For example, the instructor can introduce some recent significant or severe weather events that have occurred on the earth, such as hurricanes, tornadoes, and tsunami and use some interaction e-learning websites [7, 13] to show how these events happen and what is the damage would cause by these natural events.

Moreover, by leveraging mixed-reality (MR), bringing digital learning into another stage offers active learning methods by introducing embodied interventions. In the MR world, we can utilize all the real world elements as an object to interact with the virtual object. Furthermore, MR can bridge the communication gap between teacher and students. For instance, we can place a virtual Newton avatar on the table to teach Newton's three laws of motion, and also reproduce Trojan Horse story from the Trojan War on the table; within these two different areas of learning to arrange, we can add more interactive activities inside the MR application to provide an engagement and collaborative learning environment. Also,

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when students get lost in the MR environment, the teacher can join the session remotely to guide the student.

Nevertheless, most of the MR applications on the education area are provided visualization information from the textbook as the supplement content instead of facilitating learning through different kinds of collaborative and constructionist activities to interact in the real world [9]. Collaborative learning is a setting in which two or more people are learning or solving a problem together. During the problem-solving process in collaborative learning, students can share their ideas while others can evaluate and discuss the approach to find the solution.

RELATED WORK

In this section, the literature review of the mixed/augmented reality applications in education, with special focus on earth science subject, and some works about collaborative learning will be discussed.

Mixed Reality and Augmented Reality on Education

Carlos Delgado-Kloos et al. [8] summarized twenty-eight augmented reality projects on the educational area, and most of them used location-based and image-based approaches to guide student to explore physics, life sciences, mathematics, and earth sciences topics. However, most of these work only provides exploration or simulation activities for single student and only a few of the works includes the cooperative and collaborative concept. Shodhan et al. [12] designed Voyage which is a multiuser mobile virtual reality (VR) experience application to promote collaboration among students and teachers. The students were separated into groups, and they wore Google Daydream[1] devices to have a forest field trip in the virtual world, and the teacher used the Apple iPad[2] to guide and monitor the exploration status for all the groups. Zeynep et al. [14] studied the cognitive loads of students to learn abstract concepts in a geology course between using mobile augmented reality and traditional textbook. They used image-based augmented reality application which student can use their smartphone to scan the image on the textbook and then the virtual objects including 2D, 3D and video would be shown on the smartphone. Khan et al [9] developed a mixed reality collaborative educational application called Mathland. In Mathland, students can explore and experiment the mathematics and physics concept by using virtual items that created by the author and use the customized tangible object to interact with these virtual objects in mixed reality.

Collaborative Earth Science Education

Natalie et al. [3] built an augmented reality grand canyon field trips game, and used the location-based approach to allow students to explore the virtual grand canyon around the school campus. During the progress of the virtual field trip, students learned geologic time, geologic structure and horologic processes from the mobile devices. Chen et al. [4] used screen-based augmented reality with tangible objects to teach the earth science phenomena of day, night, and seasons for middle school students. They used three-stage instruction process to integrate with digital instruments into the education progress; 1) knowledge presentation stage, 2) exploration of the augmented reality world and 3) reinforcement stage to discover how many concepts were acquired by study.

[1]https://vr.google.com/daydream/

[2]https://www.apple.com/ipad/

APPROACH

Overview

Mixed Reality Tornado Simulator is a multi-party interaction application to teach the formation of tornado, and destructive power of tornado. Students will have the capability to work with their peers simultaneously to build the tornado by choosing different ground environment, airflow, and physical parameters.

To enhance learning performance and to reduce the cognitive load of the students, we propose a mixed reality intervention with collaborative learning in the context of tornado formation and its damage to the living place. With this research goal, it points out our research goal as following 1) How to design a collaborative learning environment (setting) in mixed reality for earth science education? 2) How to reduce students' cognitive load and increase students' motivation?

Collaborative Learning with Mixed Reality

In the classroom setting, collaborative learning not only involves jointly intellectual effort in students but students and teachers by working on interdependent learning activities [6]. With the integration of Mixed Reality, the teacher can design some experiment and activities on the virtual environment without any physical boundaries and limitation while students can explore the knowledge together by manipulating the virtual objects via a tangible or embodied controller.

Apparatus

The hardware consists of three Microsoft HoloLens, a Dell Alienware 17 (8th Generation Intel Core i7-8750H, Nvidia GeForce GTX 1080 OC with 6GB GDDR5 and 32GB DDR4 of RAM) and a wireless network router with IEEE 802.11 ac supported. The laptop is using as the server for coordinating the virtual environment and collecting the experimental data. A pair of the Microsoft HoloLens headsets is used by students to build a tornado and design the virtual city on the ground collaboratively, and another HoloLens is used by the instructor to observe and guide students during the experiment. Also, we plan to integrate HoloLens with Leap Motion sensor to detect the hand gesture for offering embodied interaction feature.

Prototype

For prototyping Multi-Party Mixed Reality Tornado Simulator, we will make terrain and environment similar to Figure 2. In our setting, the 3D topographic map will be presented on the table, and the extreme weather condition would be zoomed in between the two participants. Moreover, we will provide a toolset in the right-hand side of each participant, so they can discuss together about the environment and manipulate the weather control panel together to control the form of the simulated tornado.

In the Mixed Reality Tornado Simulator menu shown in Figure 1. The video feature plays the online education video

Figure 1. Mixed Reality Tornado Simulator - Menu & Tornado Builder

Figure 2. Microsoft HoloLens concept Idea for lighting. Adapted from "Microsoft Mixed Realtiy, https://www.microsoft.com/en-us/mixed"

about Tornado 101 [3] provided by National Geography Website which explains the formation of the tornado in details. The document feature provides the digital textbook content for students to reference the material. The setting feature enables the students to choose terrain or 3D topographic map. Ask the teacher feature enables students to invite the instructor to join the experiment session remotely to monitor and answer students' questions. Tornado builder feature, it will pop-up a button menu with three different parameter sliders; students can use the slider to change the funnel width, pressure difference and rotation speed. The test run feature, based on the intensity of the pre-built tornado and other setting such as ground temperature, students can hit the play button to see how tornado might destroy the city where that create by manipulating and placing objects into 3D scenes on Figure 1.

For offering a tangible interaction feature, students can use *Bloom* gesture, which is holding out the hand with all fingers then open the hand, to open the control menu. With *Air Tap* gesture, students can choose the feature on the menu to ask teacher, create tornado, read document, test the destructive power of tornado and modified the setting. Also, with HoloLens, students can walk around freely without the limitation of the wired-cable connected. Students can observe the tornado in different angles and discuss how to create the virtual city with the collaborators and teacher.

Experiment Design

Research hypothesis H1: Using mixed reality with multiparty collaborate learning method for learning the tornado formation and destruction would reduce the students' cognitive load compared to the web-based education application.

Research hypothesis H2: Using mixed reality with multiparty collaborate learning method for learning the tornado formation and destruction would provide profoundly immersive experience compared to the tablet/digital 2D visualization.

For H1, We will consider two different approaches to monitor cognitive load from the students. First, using the electroencephalography (EEG) device, such as InteraXon Muse[4], to monitor the brain wave activity through the study. We will analyze the brain wave difference during the learning stages of both the control group and experiment group. Secondly, we will do the qualitative analysis by studying the video and finding the nonverbal behavior of the students; such as body language and facial expression. For example, when people feel confused, they will bite their lips, crossed arms, brow furled and blinked the eye more often[2].

For H2, we want to identify the level of immersive experience in mixed reality tornado experiment by measuring the presence from the student. In order to measure the presence of the mixed reality, we plan to use Igroup Presence Questionnaire (IPQ) [11]. The questions Items (e.g." In the computer-generated world, I had a sense of "being there," Somehow I felt that the virtual world surrounded me.", "I was not aware of my real environment.", "I was completely captivated by the virtual world.") are measured in a 5-point Likert scale from 1 = strongly disagree to 5 = strongly agree.

Participants

Approximately sixty individuals, including teachers and students, from a research-partner high school in Newark, Delaware, United States will be recruited. We expect to have 50 (age 12-14) students and 10 teachers in the study. We will follow the ethics research guidelines including the IRB procedure from the University of Delaware, parental consents, children consents, and parental approval for pictures and videos.

Overview of the Pilot Study

For the pilot study, we will recruit two teachers and eight students from the nearby middle school and separated them into two groups. Each group consists of one teacher and four students.

The sessions are conducting in a classroom in the nearby high school. There are two settings for each group; the control group has four students using the tablet or digital 2D visualization while the experiment group also have four students

[3] https://video.nationalgeographic.com/video/news/101-videos/00000144-0a31-d3cb-a96c-7b3d903d0000

[4] https://choosemuse.com/

using HoloLens to learn the concept the tornado. Each session would last approximately for an hour.

Before each session starts, students are required to do the pre-test, which is based on K-12 Tornado practice questions [7]. After that, the teacher starts to teach about the formation and the destruction of the tornado for 15 minutes. Afterwards, students would be asked to create a tornado by digital instruments. Then, students will use the tornado they create to destroy the virtual city. After the experiment, students will fill out the IPQ questionnaire, and the post-test.

Case Study

For the case study, we will recruit six teachers and forty students from the nearby high school. Similar to the pilot, we will separate them into two groups so each group consists of three teachers and twenty students. We will repeat the same research and experiment procedure as mentioned in the pilot study.

Expected Findings

We expect to observe a meaningful difference on cognitive load between control and experiment groups during the session. We aim that our collected data will provide evidence to support hypothesis H1. Also, we expect to find a considerable difference between two groups on the IPQ questionnaire responses as stated in hypothesis H2.

FUTURE WORK

In this paper, we propose the research plan and the prototype of the multi-party mixed reality interaction for earth sciences education. Also, I list the related previous work, inspiring designs, educational theory, projects and mixed reality user-interface (UI) and user experience (UX) design, along with the research hypothesis and experiment design. The timeline of this work will last for a year which includes, finalizing the prototype, developing the mixed reality intervention software, preparing the institutional review board (IRB) document and send to the IRB office for approving experiment, pilot study, modify the software based on the feedback from pilot study, case study and data analysis. I expect to finish this project in the middle of my fourth year of the Ph.D. program. In the following years, I plan to increase the number of participants and build a large-scale mixed reality application and expand the collaborative learning with multi-modal deep learning method for enhancing the learning performance by providing the a personalized learning environment.

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