[DC] Learning Tornado Formation via Collaborative Mixed Reality

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ABSTRACT

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. Mixed-Reality has been shown to offer more engaging and effective learning solutions on essential science topics, such as math, physics, and chemistry. However, there are few augmented reality and mixed reality applications on earth science subject. Also, collaborative learning has been shown to be beneficial for student learning by aspiring student curiosity, and the ability of cooperation. In this paper, we propose a Mixed Reality Tornado Simulator which offers an earth science education intervention in a collaborative mixed reality setting. Students and their instructor can wear see-through head-mounted displays to cooperate on learning the knowledge of the formation and its damage cause on human-built structures, farming, and vegetation by using our proposed mixed reality application. Also, for evaluating the learning performance in this mixed reality setting, we will study the students cognitive load using standard survey instruments. We will conduct a controlled study with two conditions to compare the proposed intervention in the head-mounted-display setting, versus a desktop setting to test usability and knowledge gain of the students in those settings.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Mixed/augmented reality; Applied computing—Education—Collaborative learning

1 INTRODUCTION AND RELATED WORK

Global warming has made a significant impact on weather conditions on earth. Average temperatures have increased by 1.8 degrees Fahrenheit from 1901 to 2016 from the data in the National Oceanic and Atmospheric Administration (NOAA) [7]. Moreover, global warming also leads to Arctic Oscillation which brought more extreme weather events such as Tornados, snowstorms and strong winds in 2010 [6]. NOAA also mentioned that the ocean level is expected to rise by several inches in the next 15 years. Some coast areas will fall under the sea level which potentially causing grand damage for people.

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 educating of our students in K12 earth science classes. Moreover, with immersive technologies, the class material could go beyond the textbook and 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 [9, 11]. For example, the instructor can introduce some recent severe weather events that have occurred on the planet, such as hurricanes, tornadoes, and tsunami and use interactive digital learning tools [4, 10] to show how these events happen, and what damage would be caused by these natural events. In the earth science subject, most works are using either screen-based or mobile augmented reality (AR) [2, 3, 11]. Natalie et al. [2] 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. [3] used the screen-based augmented reality with tangible objects to teach the knowledge of earth science phenomena of day, night, and seasons for middle school students. Besides, Zeynep et al. [11] studied the difference between mobile augmented reality and traditional textbook in the values of students cognitive load while learning abstract concepts on the college-level geology course. In their work, they offered an image-based augmented reality application. The student can use a smartphone to scan the image of the geography textbook and then the virtual objects including 2D, 3D and video shown on the smartphone.

By leveraging mixed-reality (MR), bringing digital learning into another stage offers more active learning methods by introducing embodied interventions. In the MR, we can use the real world as an interface to interact with the virtual world. Furthermore, MR can bridge the communication gap between instructor and students. For instance, when students get lost in the MR environment, the instructor can join the session remotely to guide them through the adventure.

2 APPROACH

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 opportunity to work with their peers simultaneously to build the tornado by choosing the different ground environment, airflow, and physical parameters.

2.1 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 together on interdependent learning activities [5]. With the integration of MR, the teacher can design some experiment and activities on the virtual world without any physical boundaries and limitation while students can explore together by manipulating the virtual objects via a tangible or embodied controller.

2.2 Prototype

For prototyping Multi-Party Mixed Reality Tornado Simulator, we create a virtual terrain and atmospheric environment in the classroom where the 3D topographic map will be displayed on the table, and the extreme weather condition would be zoomed in between the participants. Further, we will provide a toolset in the right-hand side of each participant, so they can discuss together the environment and manipulate the weather control panel together to control the form of the simulated tornado.

The Mixed Reality Tornado Simulator menu has six different features as shown in Figure 1. The video feature plays the online education video about tornado 101[1] provided by National Geography which explains the formation of the tornado in details. The document feature provides the digital textbook content for students

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

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Figure 1: Mixed Reality Tornado Simulator

to reference the material. The setting feature enables the students to choose a terrain or 3D topographic map. Ask the teacher feature allows students to invite the instructor to join the experiment session remotely to monitor and answer students questions. Tornado builder feature controls some features for the formation of Tornado. When pressing this button, the play button menu will pop up with three different parameter sliders for adjusting funnel width, pressure difference and rotation speed of the tornado. 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.

3 Experiment Design

To evaluate the proposed mixed reality application, we make two hypothesis to provide a testable setting to work on.

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

H2: Using mixed reality with multi-party collaborate learning method for learning the tornado formation, and destruction **would provide profoundly immersive experience compared to the desktop/digital 2D visualization.**

For H1, we aim to study the difference of cognitive load from the students while they are experimenting with the see-through head-mounted-display (Microsoft HoloLens) or web-based applications. We will do the qualitative analysis by analyzing the video and finding the nonverbal behavior of the students to examine the cognitive load; such as body language and facial expressions revealing frustration or other indicators of the high-cognitive pressure. For example, when people feel confused, they will bite their lips, cross the arms, brow furled and blink more often [1].

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) [8]. The questions items (e.g., In the computer-generated world, I had a sense of being there, I was completely captivated by the virtual world.) are measured in a 5-point Likert scale from 1 = strongly disagree to 5 = strongly agree.

3.1 Participants

Approximately sixty individuals, including teachers and students, from a research-partner high school will be invited to participate in the study. We expect to have 50 (age 12-14) students and 10 teachers in the study. Parents will be contacted via email to include their children in our studies. 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.

3.2 Study Design

We plan to conduct both the pilot study and case study for evaluating the Multi-Party Mixed Reality Tornado Simulator. The experiment place will be held in the classroom of the nearby high school. Students in the control group use the web-based application on a Desktop PC to participate in the interactive activity while the students in the treatment group will use the Microsoft HoloLens.

Before the study session starts, students are required to do the knowledge test as the pre-test, which based on K-12 Tornado practice questions [4]. Afterward, the teacher starts to teach about the formation and the destruction of the tornado for 15 minutes. Following the knowledge presentation phase, the students will be asked to create the tornado by digital instruments. In the meantime, researchers will do on-site evaluative observations on the whole interactive activity for subsequent qualitative analysis. Later, students will test the tornado by destroying the virtual city. After the interactive activity, students would be asked to fill in the IPQ questionnaire and post-test. With this study design, it brings out our research goals

1) How to design a collaborative learning environment in mixed reality for earth science education?

2) How to reduce students cognitive load and also increase motivation at the same time?

We expect to observe a meaningful reduction on cognitive load among experimental group in comparison to control group during the intervention.

Finally, this ”tornado experiment” is only the initial stage of the multi-party mixed reality interaction for education explicitly focusing on Earth Education. In other words, there will be more advanced experiments to come regarding different natural disaster based on the experimental result from the primary tornado study.

References

[1] J. K. Burgoon, L. K. Guerrero, and K. Floyd. *Nonverbal communication*. Routledge, 2016.

[2] N. Bursztyn, A. Walker, B. Shelton, and J. Pederson. Increasing undergraduate interest to learn geoscience with gps-based augmented reality field trips on students' own smartphones. *GSA Today*, 27(5):4–11, 2017.

[3] C.-p. Chen and C.-H. Wang. Employing augmented-reality-embedded instruction to disperse the imparities of individual differences in earth science learning. *Journal of Science Education and Technology*, 24(6):835–847, 2015.

[4] CK12Foundation. Tornado, 2018. `https://www.ck12.org/Earth-Science/Tornadoes/?referrer=concept_details`, Accessed:11/09/2018.

[5] P. Dillenbourg. *Collaborative learning: Cognitive and computational approaches. advances in learning and instruction series.* ERIC, 1999.

[6] NOAA. Arctic oscillation, 2018. `https://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/ao.shtml`, Accessed:1/11/2019.

[7] NOAA. Climate change, 2018. `https://www.noaa.gov/news/federal-climate-science-report-for-us-released`, Accessed:1/11/2019.

[8] T. Schubert, F. Friedmann, and H. Regenbrecht. The experience of presence: Factor analytic insights. *Presence: Teleoperators & Virtual Environments*, 10(3):266–281, 2001.

[9] S. Sharan, K. Julian, M. Rajeev, K. Na-yeon, H. Sijia, J. Balash, and M. J. W. Lee. Fostering collaborative interactions in the classroom using mobile vr. ACM, 2018.

[10] N. S. P. team. Scikinks:tornado simulator, 2018. `https://scijinks.gov/tornado-simulation/`, Accessed:11/09/2018.

[11] Z. Turan, E. Meral, and I. F. Sahin. The impact of mobile augmented reality in geography education: achievements, cognitive loads and views of university students. *Journal of Geography in Higher Education*, pp. 1–15, 2018.