AC 2012-5327: USABILITY OF A COLLABORATIVE VIRTUAL REALITY ENVIRONMENT EARTHWORK EXERCISES

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Tulio Sulbaran received his Ph.D. in civil engineering from Georgia Institute of Technology with a concentration in construction management and with a minor in computer engineering and strong statistical background. He has more than eight years of work experience in the A/E/C (architecture, engineering, and construction) industry with office and field experience in scheduling, estimating, and project management in the United States and several international locations, including Venezuela, Singapore, Brunei, Malaysia, and Thailand. Sulbaran is an accomplished teacher and has taught a variety of construction courses, including Construction Planning and Scheduling, Construction Project Management, Cost Estimating I, Project Control, Proposal Preparation, and Project Implementation, among others. Sulbaran received the prestigious John Trimmer Award for Excellence in Teaching in 2010. Sulbaran engages students in learning activities inside and outside the classroom continuously advocating hands-on experience and collaborative learning. He has been in the forefront of online teaching, and he was one of the pioneers in delivering online courses in the School of Construction. He established the Study Abroad program in Panama at the University of Southern Mississippi. Sulbaran led the effort to establish the newly created master's of science in logistics, trade, and transportation (MSLTT), and he is currently leading the effort to put the MSLTT fully online to further the educational reach of the university. Sulbaran has the best externally funded projects track record of the School of Construction. He has submitted as PI/Co-PI more than 100 proposals and has been awarded more than 40 externally funded projects, totaling more than $10 million. Additionally, he has been collaborator in multi-million, multi-institution proposals with institutions in the United States and abroad. Sulbaran has received funding from several organizations, such as the National Science Foundation, Mississippi Department of Transportation, Transportation Research Board, Northrop Grumman, Mississippi Development Authority, Army Corp of Engineers, and Department of Health and Human Services among others. Sulbaran founded the Center for Logistics, Trade, and Transportation, and all of his projects have supported and benefit from talented graduate and/or undergraduate students from a variety of academic units in the university. Sulbaran has been very prolific in the area of scholarship and research. He has authored more than 60 peer-reviewed national/international publications, written several books, and made more than 100 professional presentations nationally and internationally. Sulbaran's manuscripts have been published in the International Journal of Technology, Knowledge, and Society, the International Journal of Virtual Reality, the Journal of Marketing Education, the Marketing Education Review Journal, the IEEE- Frontiers in Education, and the American Society of Engineering Education Proceedings, among others. Sulbaran has contributed significantly to his discipline through his service activities. His leadership on several key organizations has reflected very favorably on the university. Sulbaran is the first and only faculty of the University to hold a Board of Trustee position in the American Council for Construction Education. He is also the first and only faculty serving as the Editor for the Associated Schools of Construction proceedings. Sulbaran has served in multiple university committees, such as the I-TECH Customer Service Council, the CoST Research Award Committee, the CoST Scholarship Committee, and the SoC Accreditation Committee, among others.

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Usability of a Collaborative Virtual Reality Environment Earthwork Exercises

Abstract

A variety of visualization mediums are needed to help students comprehend a subject matter. Current visualization mediums include graphs, drawings, and various other two dimensional visual aids. While these mediums work for some students, others tend to need a better visual to reiterate the concept. For example, students in building construction management courses depend on pen and paper pedagogy to learn how to properly excavate a project site. Using pen and paper, these students answer questions and get a response based on their answers in a form of a grade. According to the United States Department of Labor, excavating is "one of the most hazardous construction operations" [8] which means students need a better visualization than the grade as a result of the wrong choices of how to make the excavation. For example, if the student was asked to use the Occupational Safety and Health Administration (OSHA) rules in order to select the correct slope method for an excavation in a given soil type they would simply select an answer based on their understanding of OSHA soil types and excavation methods. The result of their answer using the current pen and paper pedagogy would be either a red mark indicating the incorrect answer which would result in a grade deduction or a check mark indicating the correct answer without a deduction in grade. In real life, the consequence of selecting the wrong method of excavation would be more dangerous as it could cause a collapse resulting in employee injury [8].

The visual of a right or wrong answer that is provided to the student could be improved by using a growing field in technology, simulations in Collaborative Virtual Reality Environments (CVRE). Simulations in CVRE provide the ability to implement an excavation training simulator in a CVRE so that students could receive a visual and immediate form of feedback in order to see how their answer could impact the excavation method they select. In addition to providing the students with feedback, they can also interact with other students or professor in order to discuss the meaning of the different methods or can be shown the right and wrong method through professor guided examples. While excavation training simulators exist, including the Southwest Research Institute's Excavator Operator Training Simulator and The University of Hong Kong imseCAVE, they were implemented using methods that might not provide the ability to quickly add features to the simulation while addressing the breadth and depth of immersion so the student will feel as if he or she is at the actual job site [1,5]. In order to prove that an excavation training simulator can act as a positive visual aid, it first must be usable. This paper discusses implementing and determining the usability of an excavation training simulator for Perdue University

Keywords: Earthwork, Education, Virtual Reality, Collaboration

Introduction

Students in a Building Construction Management course at Purdue University currently use pen and paper pedagogy to learn the proper methods for excavating a project site. In order to learn how to excavate a construction site, the students draw and submit a plan view of a building excavation where they select a slope on the basis of a soil description. The soil descriptions selected by the student are outlined in the soils type section of the Occupational Safety and Health Administration (OSHA) manual. Educators rely on these 2D drawings, graphs, models, and charts as visual aids for learning the excavation process as the only method for visualization when other methods could be utilized. While the returned grade as a result of a check for correct answer and an x for an incorrect answer is a form of feedback from an in-class exercise, this form of feedback is not given back immediately. As students that decide to work in this field will be dealing with these questions in real life where the result being successful or dangerous is given in real-time, a better visual could be given in order to ensure the student comprehends the task. By developing an excavation training simulator in a Collaborative Virtual Reality Environment, students can receive intermediate feedback from the selections they choose. While the key is to provide another form of visualization, the excavation training simulator, visualization tool, is not beneficial unless it is usable by the students. This paper discusses the results of an excavation training simulator test case with Building Construction Management students at Purdue University in order to provide a visualization of the excavation process that would be usable for their Construction Site Planning course.

Background

Although the usability of Collaborative Virtual Reality Environments has been a subject of considerable academic interest, few concrete tests have been done on live subjects to determine actual usability as experienced by motivated users such as students [2, 6, 7]. Having a form of visualization that is usable and helps the students better understand the excavation process is very valuable as the effects of improper excavation is less dangerous to learn via simulation than in real-life experiences. For example, OSHA cites open trench work as the fourth deadliest job in United States [4]. Thus, it would be beneficial to the student and construction employers if a usable and realistic visualization tool could be developed for training students how to properly excavate. This paper presents the results of assessing the usability of an excavation training simulator built for Building Construction Management Students at Purdue University using a communication protocol designed by Lacey Duckworth as part of her dissertation studies at The University of Southern Mississippi.

Learning Objectives

When making an excavation, wider excavations may seem less restricted in movement and thus less dangerous in the event of slope failure. However, during construction operations the gap between a slope toe and an immovable object on the floor of the cut may be reduced to mere trench widths (15-feet or less) and jeopardize workers as much as do narrow trenches. All excavated slopes rightfully comply with OSHA standards therefore making it critical to ensure students understand the appropriate process and standards before entering the workforce.

The architecture for implementing this simulation is unlike other simulations for CVREs. Existing methods for implementing a simulations within CVREs requires embedding the actual simulation within the CVRE, which can cause performance and scalability issues as well as limit the pieces of simulation to be implemented due to script size limits. Performance issues occur because the server remains busy at all times updating the environments appearance and maintaining user information. Scalability issues arise because there is no other method for quickly adding methods to the simulation which requires a complete rewrite of the script. The solution for this is to move the simulation external to the CVRE which entails the network architecture as seen in figure 1, the communication protocol diagram. The idea is to let the simulation language perform the calculations and report back to the CVRE the visual to be made. The reason for using this protocol for designing the simulation is to provide the ability to make simple edits to the diagram and have the information needed to add elements to the simulation. This is a new developed protocol that has potential for replacing the existing architecture for developing simulations inside of CVRE. While the main purpose of utilizing this architecture is to develop a CVRE for earthwork exercises, the underlying purpose of this implementation is to determine if the proposed architecture is suitable for such implementations.

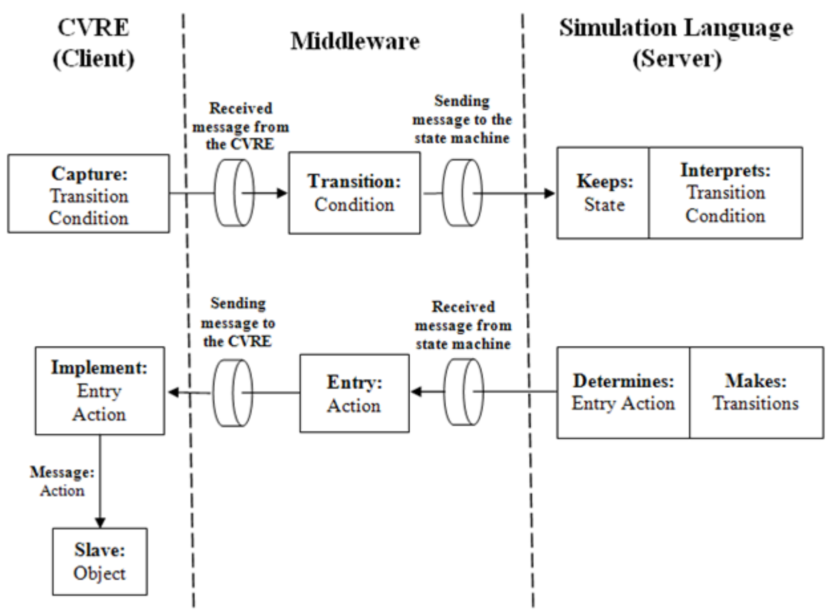

Figure 1: Communication protocol diagram used for developing the Simulation in the Collaborative Virtual Reality Environment

Using this architecture, the excavation training simulator was implemented so that students could answer the following questions

- What soil type does the exercise best describe?
- What is the appropriate slope method for the soil type provided?
- What is the appropriate height/depth ratio for the soil type and slope method selected?
- What is the correct bank measure volume of the excavation?

Based on their selections, the program provided prompt feedback, which could be either a successful or failed excavation. A successful excavation shows the project site being excavated. On the other hand, an excavation fails when the user selects a slope that is too steep for the soil type, which results in a small landslide occurring partially burying the excavator. Figure 2 below shows the interaction board that contained the questions with buttons for interacting with the board.

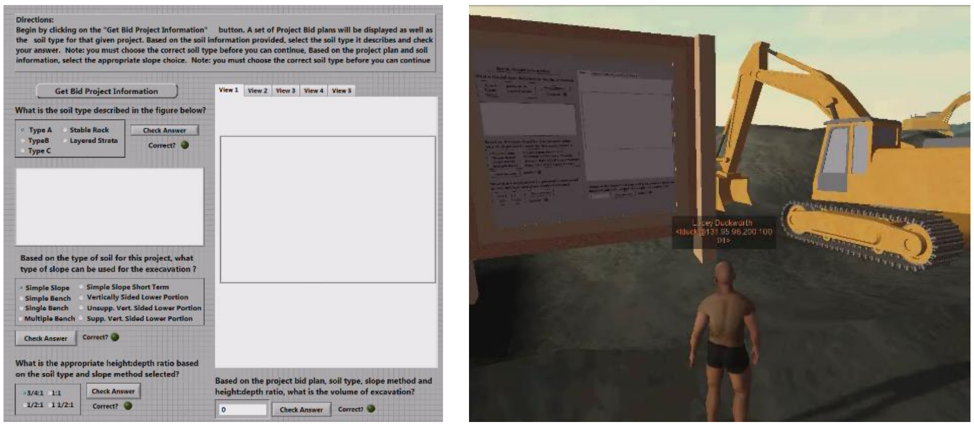

Figure 2 – interactive board in the CVRE.

Experiment

The purpose of this experiment was to make sure that the simulation embedded in the CVRE through use of the communication protocol diagram provided a usable training simulator for Dr. Rapp's Construction Site Planning students. The experiment consisted of twenty six Purdue University students from Dr. Rapp's Construction Site Planning course who volunteered to log into the CVRE and complete the excavation training simulator exercise with the aid of a written tutorial. Once completing the training simulator in the CVRE, students were asked to complete an online survey in order to determine their degree of usability. The usability survey was designed based on the Guidance on Usability from the International Organization for Standardization (ISO). This document is a measuring device to ensure that the design and evaluation of visualization tools enables users to achieve goals as well as meet the needs in a particular context of use .[3] In the ISO guidance on Usability manual several categories are developed in order to measure the usability of visualization mediums such as this excavation training simulator. These categories include:

- Suitability of the task,
- Self-descriptiveness,
- Controllability,
- Conformity with user expectations,
- Error tolerance,
- Suitability for individualization,
- Suitability for learning interest/enjoyment

Using these categories, a 24 questions survey was developed in form of a statement where the student could choose strongly agree, agree, undecided, disagree, or strongly disagree. In order to develop the questions, an example questionnaire provided in the Guidance on Usability from the International Organization for Standardization was used as a reference point for generating each of the questions. While all questions on this survey appear in the appendix, below are examples of questions on this survey from each of these categories include:

- There were times when more information or additional tools were needed but unavailable.
- The instructions for each task were easy to understand.
- The instructional material was organized and easy to locate.
- The instructions and feedback were consistently arranged.
- It was easy to correct errors encountered in the simulation environment.
- The instructional material was available at convenient hours of the day.
- The instructional material provided opportunity for decision making.

In additions to the statement questions, students were also given two questions:

- Did they think this activity should be available to upcoming students?
- Should this activity be modified for the upcoming students? If so, what modifications?

Once the data was collected from these surveys, the questions were grouped by the categories and statistical methods were use to determine the degree motivation for each section.

Results

The figures below display the results of the motivational survey based on the categories: interest/enjoyment, perceived competence, effort/importance, pressure/tension, perceived choice, and value/usefulness.

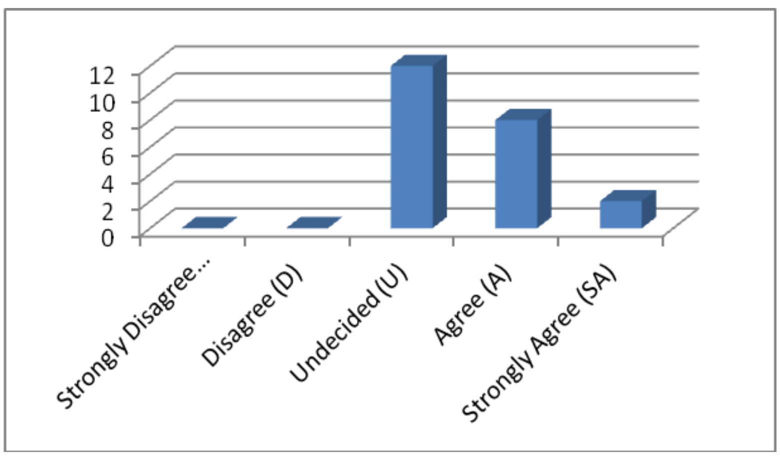

Figure 3. Chart displaying the extent of the suitability for the task

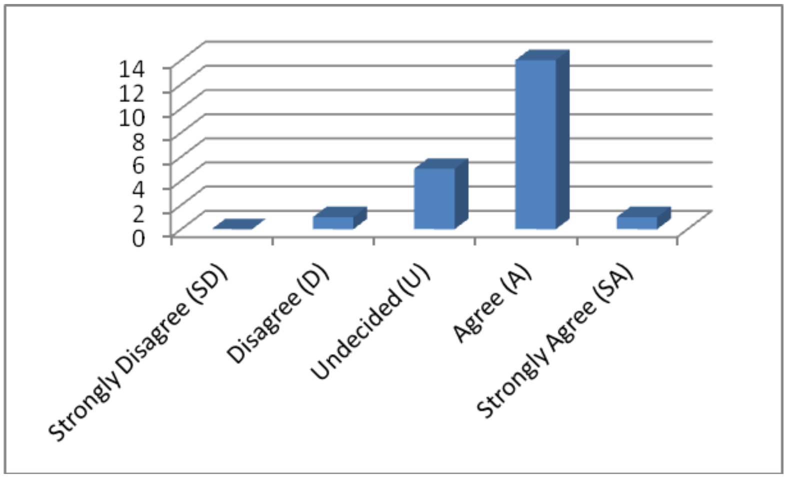

Figure 4. Chart displaying the self-descriptiveness of the activity

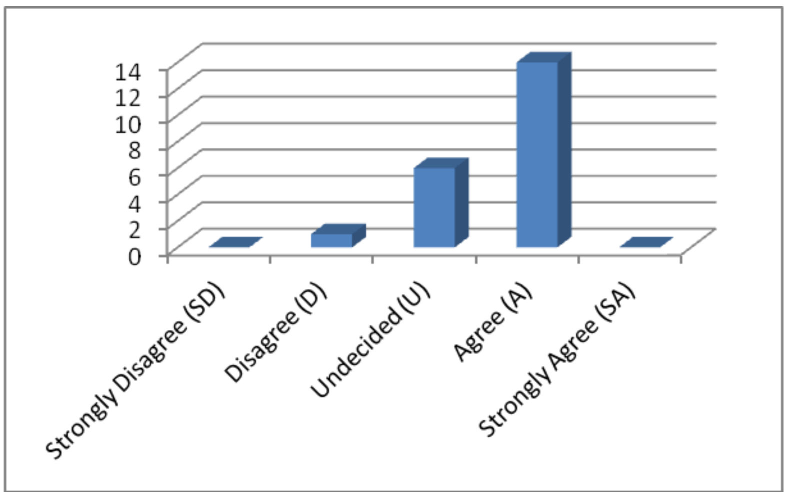

Figure 5. Chart displaying the extent of controllability felt by users

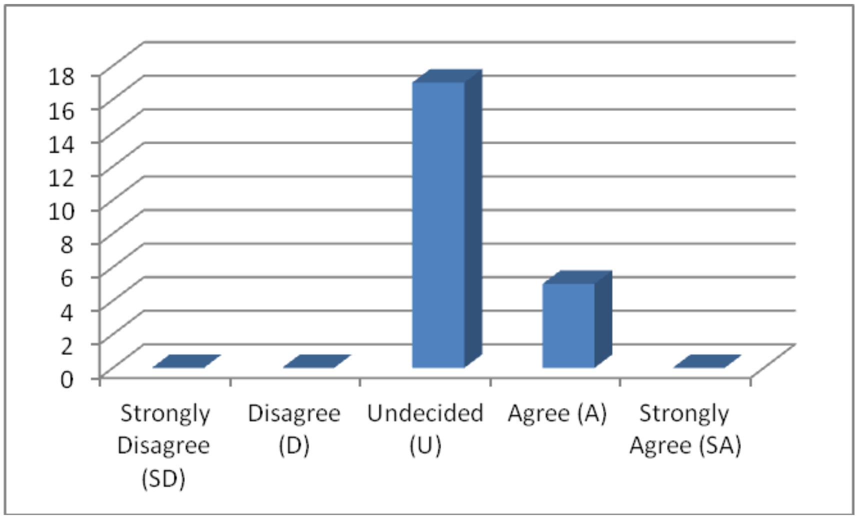

Figure 6. Chart displaying the conformability with the users expectations.

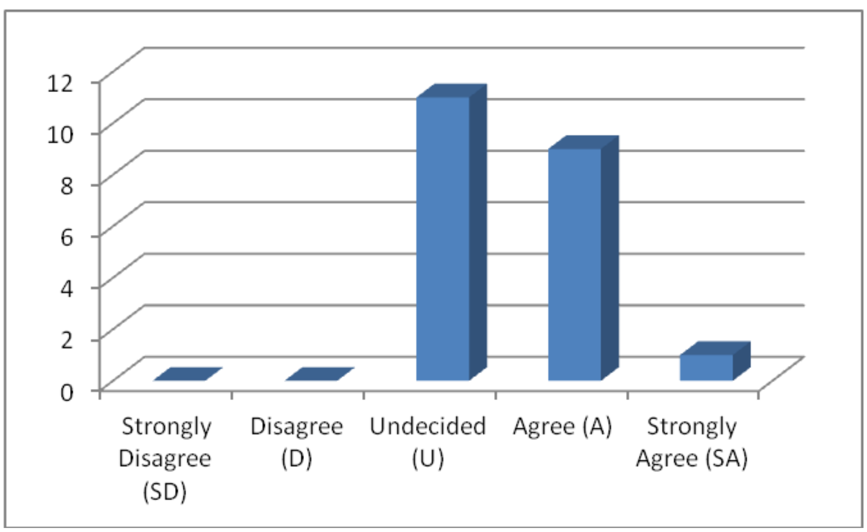

Figure 7. Chart displaying the error tolerance of the activity

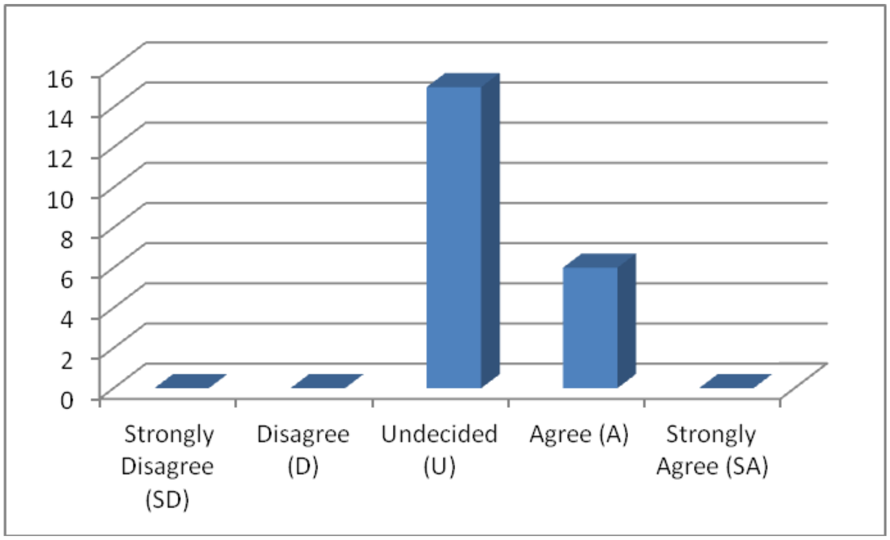

Figure 8. Chart displaying the suitability for the individualization of the activity

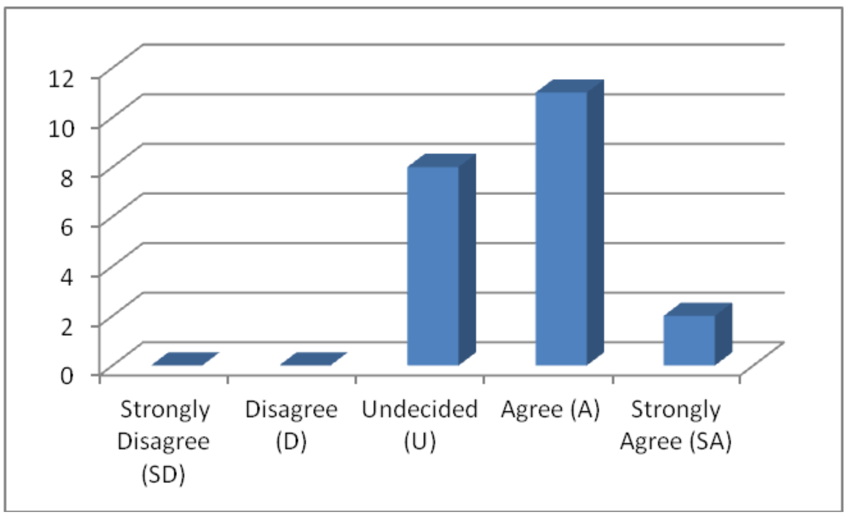

Figure 9. Chart displaying the suitability for learning for this activity

By using the information gathered from this test case, if changes were made to improve the training simulator, there is a strong chance that students who were undecided might change their answer to the survey questions to indicate they agree or strongly agree with the statement about the training simulator.

Future Works

Based on the feedback from the test case, enhancements need to be made to the training simulator so that students will find it usable and it would be a valuable visualization tool for educators. Enhancements to the training simulator require adding code to prevent students from skipping ahead or going back to other questions, and providing indicators for answers submitted. After implementing these enhancements, another test case would be performed in the same manor of the first test case resulting in a usability survey after the experiment.

Summary

The purpose for implementing an Earthwork Exercise simulation for students in a Building Construction Management Course was to find a usable medium for teaching earthworks exercises and determine if the architecture used to implement this simulation was suitable for such developments. As seen in the results, the simulation built using this architecture needed to be refined as there were some issues indicated in the results. Although modification was needed to the code in order to make the simulation in the CVRE more usable, the architecture for developing the simulation in the CVRE proved to be sufficient as all the components to implement the simulation in the CVRE were identified and the ability to move the simulation external to the CVRE was successful. While more work is to be done in order to measure the success in using this architecture to develop simulations the main focus of this paper was to implement the earthworks simulation which resulted in sufficient information for making the simulation more useful.

Appendix

For the first set of questions students could answer Strongly Agree, Agree, Undecided, Disagree, or Strongly Disagree.

1. Appropriate help was easily accessible whenever additional explanation was requested.
2. The steps required for completion of each task were necessary.
3. There were times when more information or additional tools were needed but unavailable.
4. The instructions for each task were easy to understand.
5. Adequate feedback was provided at the appropriated time.
6. The feedback provided was useful
7. The materials were easily accessible
8. All aspects of the learning interface were clearly labeled.
9. The instructional material was able to be obtained in a timely manner
10. It was easy to refer back to the previously used instructional material.
11. The instructional material was organized and easy to locate.
12. It was sometimes difficult to locate the desired instructional material.
13. The instructions and feedback were consistently arranged.
14. Appropriate instructions on how to proceed were provided when an error was encountered in the environment.
15. Appropriate explanations were provided to minimize errors while achieving the instructional objectives.
16. It was easy to correct errors encountered in the simulation environment.
17. The available tools and instructional material functioned as expected.
18. The instructional material was available at convenient hours of the day.
19. It was easy to stop the learning material and come back later to begin again at the previous stopping point.
20. The user was able to complete a task using more than one approach.
21. All of the instructional material supported the objective of the learning material.
22. The instructional material provided opportunity for decision making.
23. The instructional material was structured in such a way to encourage learning.
24. The materials and activities provide a challenging learning experience.

The next set of questions, student could answer Extremely, Very, Somewhat, Not very or Not at all.

1. How helpful was IN GENERAL the learning material?
2. How helpful was the INSTRUCTINAL OBJECTIVE of the learning material?
3. How helpful was the ENVIRONMENT LOG-IN INSTRUCTIONS section of the learning material?
4. How helpful was the ENVIRONEMENT NAVIGATION INSTRUCTIONS section of the learning material?
5. How helpful was the ENVIRONMENT DOWNLOAD section of the learning material?
6. How helpful was the ENVIRONMENT USER ACCOUNTS section of the learning material?

For the next set of questions students could answer yes or no.

1. Should this activity be accessible to the upcoming students?
2. Should this activity be modified for the upcoming students?

The next questions allowed students to key in their own personal answer.

1. If you thought this activity should be modified for the upcoming students, what modifications would you suggest to make this activity a better educational experience for those students?
2. Comments.

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