ASSESSING THE EFFECTIVENESS OF VIRTUAL ENVIRONMENTS FOR LEARNING THE FUNDAMENTALS OF SURVEYING AND CONSTRUCTION LAYOUT: INITIAL FINDINGS

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ABSTRACT

The practice of Surveying and Construction layout is one of the fundamental skills that need to be acquired by an engineering or construction management student. Mastering these skills requires extensive training with the equipment and working with team members in order to achieve both precision and accuracy in measurements. In addition to learning how to use the surveying instruments, mastering surveying techniques requires the students to follow complex procedures accurately. This paper describes the development of a prototype Virtual Environment for learning surveying concepts and practices, and reports and discusses the results of an initial evaluation of the Virtual Environment with a group of undergraduate students at Purdue University. The prototype tool described in the paper includes one educational module and it is a first step toward the development of a Virtual Reality (VR) surveying education tool (with 5 educational modules) that will be integrated in surveying courses as a preparation, revision and assessment tool. Findings from the initial evaluation show that students reacted positively toward the Virtual Environment, were engaged with it and found the tool to be very valuable. In addition, results demonstrate that the prototype program is a very effective assessment tool for measuring the individual student level of competency in chaining

Keywords: Education, Construction, Construction Layout, Surveying, Virtual Environment

1. INTRODUCTION

Surveying is a core course in the Civil Engineering, Building Construction Management, Geomatics, Agriculture and Forestry, and Landscape Architecture curricula. Surveying is the science of studying the 3D shapes of the earth curvature. Surveying concepts are founded in geometry and vectors principles, and the application of Surveying requires the understanding of basic methods and procedures to achieve the desired precision and accuracy. In the context of construction layout, angles, distances and elevations are used to set up the building footprint at the correct location, establish level elevations and plumb vertical surfaces.

Traditionally, teaching surveying courses includes three components: (1) the theoretical foundation of surveying, which includes math, trigonometry, geometry concepts, usually taught in classrooms using examples from textbooks and illustrations on the board. (2) Instructor demonstration of functionality and manipulation of real surveying instruments. (3) Student practice in groups with instruments.

Teaching Surveying and Construction layout presents several challenges that can be categorized based on the perspectives of Students, Teachers, and Universities. Table 1 summarizes the needs of the students and the respective challenges that can cause the faculty and the academic establishments to satisfy the student needs. The students needs can be viewed as challenges for teachers and universities. In addition to the challenges summarized below in table 1, traditional teaching of construction surveying can be influenced by the weather, location and time of day.

Presently, another problem in teaching surveying is what R. Elgin calls "The Demise of Basic Surveying Mathematics" (The American Surveyor, May 2007). Elgin reports "..a distinct decline in the math skills of students taking surveying courses… In the 'old days' the students' general knowledge of algebra, trigonometry and geometry was excellent… Most of that has changed for the worse. The entering students' knowledge of basic math concepts has sunk to such a low level in the past five to ten years, that for all practical purposes I can say they have virtually none when it comes to being prepared to attack surveying..". Thus, there is a strong need to provide the students with effective ways to improve understanding the mathematical concepts and the application of these concepts in surveying.

Students Needs	Associated Challenges	
	Teachers Perspective	University Perspective
One to One Mentoring and Guidance	Increase numbers of trainers to equal number of students	Additional cost for trainers
Additional Time to practice with equipment	Additional hours to be available for students	Additional cost for hours of availability for training
Less dependency on team members	Students to work with trainers instead of students	Increase number of equipment, One set of equipment per student
Immediate feedback on Accuracy of measurement	Trainer available every step of the way	
Access to Standardized equipment		Cost of continuously standardizing the equipment
New practice fields	Think of new exercises in new settings and locations	Provide locations for training

Table 1: Students needs and associated Challenges in Teaching Surveying and Construction Layout

2. BACKGROUND: INTERACTIVE VIRTUAL ENVIRONMENTS AND LEARNING

An Interactive Virtual Learning Environment (VLE) is defined as a designed information space in which the information is explicitly represented, educational interactions occur, and students are not only active, but actors, i.e., they co-construct the information space (Dillenburg, 2000). The pedagogical benefits of interactive virtual learning environments have been examined (and are currently being examined) by researchers in the areas of computer graphics, cognitive psychology, visual cognition, and educational psychology. In general, research findings show that virtual learning environments can be more effective than traditional teaching tools (Dalgarno 2004; Shin 2003; Winn 2002). Research also shows that VR technology is particularly suitable to mathematics and science education. VR technology presents concepts in concrete terms and offers a valuable alternative to the conventional study of mathematics and science, which is based primarily on textual descriptions and 2D representations (Johnson 2002).

Technologies, such as VR, can be used to create interactive learning environments where learners can visualize concepts easily and receive feedback to build new knowledge and understanding (Barron 1998; Bereiter 1993; Hmelo 1998; Kafai 1995; Schwartz 1999; Bransford 1999). VR also supports learning in a nonlinear

fashion, which has been shown to be effective in teaching students how to be critical and creative thinkers (Strangman 2003). Computer simulations have been shown to be an effective approach to improve student learning and have the potential to help students develop more accurate conceptions (Jiang 1994; Kangassalo 1994; Zietsman 1986; Brna 1987; Gorsky 1992). Research shows that the use of simulation tools often reinforces learning and leads to performance improvements in a variety of disciplines. Therefore, recently, there has been significant progress in development of computer-based tutorial systems in many different areas.

Though progress has been less evident in engineering education (Mosterman et al. 1996), there are some noticeable examples of engineering virtual laboratories. For instance, Del Alamo (Mannix 2000), a professor of electrical engineering at MIT, created a web-based microelectronics lab for his students in 1998. At Johns Hopkins University, Karweit (2005) has simulated various engineering and science laboratories on the web. At the University of Illinois Urbana-Champaign (UIUC), researchers have developed a virtual laboratory for earthquake engineering (SSTE 2005).

In the area of surveying, Kuo et al. (2007) have recently developed a virtual survey instrument (SimuSurvey) for visualizing and simulating surveying scenarios in a computer-generated VE, and studied the feasibility of introducing SimuSurvey in regular surveyor training courses. Results of the study indicated improved student learning outcomes and positive attitude toward including SimuSurvey in regular surveyor training courses. At Leeds Metropolitan University, UK, Ellis et al. (2006) have developed an undergraduate VR surveying application. The interactive software includes 360-degree panoramic images of sites and makes use of QuickTime VR technology. The application was evaluated with 192 undergraduate students; findings suggest that the interactive tool complements traditional learning approaches, maintains student interest, and reinforces understanding. At University of New Castle, UK, Mills and Barber (2008) have implemented a virtual surveying field course which includes both a virtual fieldtrip and a virtual interactive traverse learning tool (VITLT). The goal of the tool is to improve understanding of surveying methods for first year students in the Geomatics degree. The application was evaluated by several Geomatics students; all subjects highlighted the potential of VITLT to help the learning and understanding of a traverse. However, the students did not see the e-learning tool as a replacement for a traverse observation as carried out on the fieldcourse, but suggested that it could be used as a preparation and revision tool.

Although some authors have documented that VR experiences provide advantages over more traditional instructional methods (Ainge 1996 and Song 2000), studies of VR projects are still relatively rare and a need exists for investigations of VR in the undergraduate classroom (Strangman 2003).

3. THE PROTOTYPE VLE TOOL

The overall goal of our work is to develop a Virtual Learning Environment that can overcome many of the challenges described in section 1 by providing (1) 24/7 access to surveying equipment and practice exercises; (2) Immediate feedback on students' performance; (3) Assistance and guidance in the learning process; (4) A 'virtual math tutor' that explains and reviews the fundamental mathematics concepts on which surveying is founded; (5) Less dependency on team members (students are able to work individually and at their own pace); and (6) Access to "standardized" virtual equipment (this eliminates the risk of working with erroneous equipment). The VLE will be integrated in surveying courses as a preparation, revision and assessment tool. Using the VLE, students will learn surveying concepts, the mathematical concepts that support this science and its practices through interaction with virtual surveying equipment in a virtual environment.

The authors experienced that students tend to focus on learning how to operate the Surveying equipment, rather than on the methods and procedures that lead to accurate and precise results. Often, students are unable to make connections between the theoretical concepts explained in class and the practice in the field. Therefore the focus of the VLE is on the methodology, techniques and procedures that the student should follow in order to achieve accuracy and precision.

To date we have developed a prototype VLE which consists of a single lesson/activity. The prototype was developed using the XNA framework as the base game engine. Screenshots of the prototype application are shown in figure 1; a video demonstration of the program can be viewed at: http://www2.tech.purdue.edu/cgt/i3/VELS/ . The educational content of the prototype focuses on chaining. The goal of this first educational module is to help students visualize and apply the concepts of chaining in the

following scenarios: horizontal plane; steep slope; rough terrain; error of standardization of steel tape; error due to temperature; error due to both temperature and standardization. The prototype includes reference documentation on surveying methods and the students learn and practice how to measure the horizontal distance between two points using the proper techniques and instruments. The student's information and activities, such as time spent on the lesson, critical decisions made, and the actual measurements made by the user, are recorded and saved to a spreadsheet file that can be accessed by the instructor.
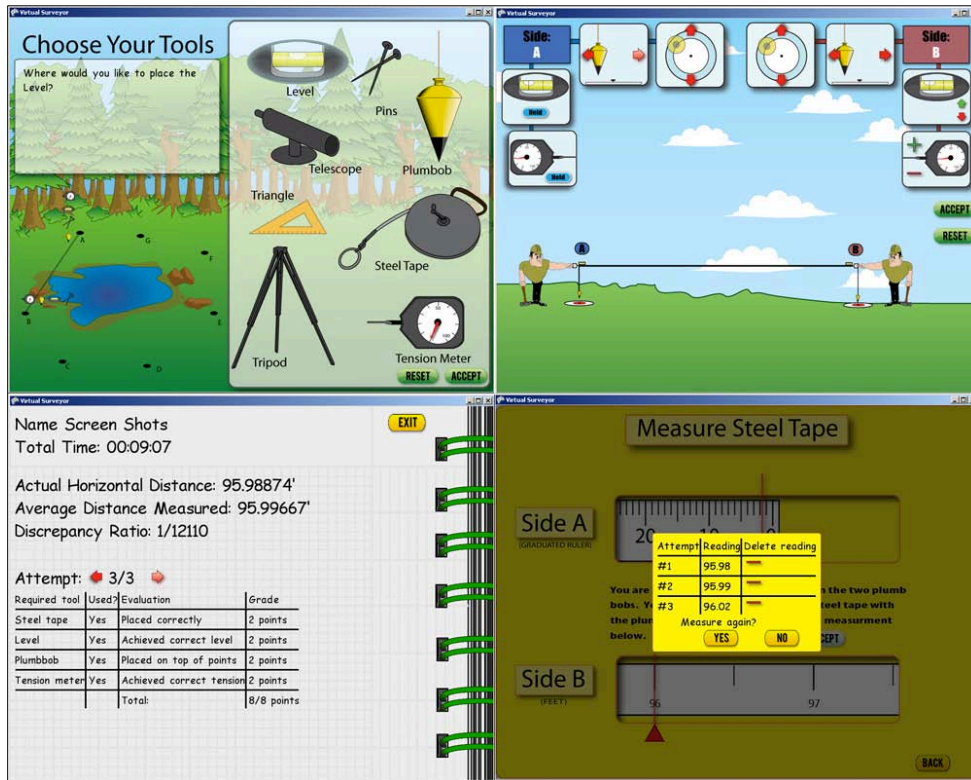

Figure 1. Screenshots of the prototype VLE. Clockwise from top left: (1) Selection of instruments and their location. (2) Illustration of random initial settings of the instruments, students are required to adjust the settings. (3) Illustration of measure steel tape, students are required to read the steel tape by adjusting the "Add-tape" concept, and then record the measurement; afterward, they are prompted to move on to repeat the measurement or proceed to complete the exercise. (4) Summary of the student's performance in the exercise.

4. INITIAL EVALUATION

The prototype was evaluated with 27 volunteers from the 117 undergraduate student population enrolled in the Surveying and Construction Layout class in the department of Building Construction Management at Purdue University. The prototype was introduced to the students at the very end of the Spring semester, therefore its effectiveness as a learning tool could not be assessed during this first evaluation. The objective of this preliminary study was to gather data on the students' reactions toward the technology, and on the tool's effectiveness at measuring and assessing the individual student level of competency in chaining. Usually, students are required to take a proficiency test at the end of the semester to show their proficiency skills in using the various surveying equipment. Chaining, i.e. the use of the steel tape to measure horizontal distances, is one of the very first exercises the students have to master. The prototype VLE is an interactive simulation of the chaining exercise. The students used the VLE to demonstrate their working knowledge of the tools and procedures necessary to successfully complete the chaining task. Consecutively, the students were asked to perform a similar chaining exercise, where they used actual instruments and needed the assistance of a team member to complete the exercise.

The chaining exercise required students to measure the horizontal distance between 2 points. The VLE presented the students with a representation of a terrain, with various points marked down. The students were instructed to measure the horizontal distance between two given points. The VLE tracked all the steps undertaken by the students to complete the chaining exercise. Table 2 shown above represents the various user steps tracked by the VLE.

Student ID	This field is entered by the student, will show the student name or ID number
Total time	Time needed to complete the attempt/Assignment
Tool selection	The VLE documents the tools selected by the students to complete the exercise. The VLE also documents the number of attempts the student undertakes in order to select the tools needed for the exercise, and whether the student requested the help of the VLE to complete this step
Record of excess tools chosen	The VLE records the tools selected in Excess i.e. the instruments that are not required to complete the exercise
Tools Justification	This is a narrative part, where the student enters the justification for the choice of tools
Tool procedure	The VLE documents the proper use of the equipments, i.e. correct placement
Adjustment of Plumb bob along X-axis	The VLE documents the proper adjustment of the Plumb bob to make sure it is positioned above the point of interest along both the X and Z axis
Adjustment of Plumb bob along Z-axis	
Correct Level Adjustment	The VLE documents the proper adjustment for the correct levelness of the tape
Correct Tension Adjustment	The VLE documents the proper adjustment for tension in the tape
Record of student measurement	The VLE records the students various measurements
Actual Horizontal distance	The VLE records the true measurement
Record of Deleted measurements	The VLE documents the deleted measurements, identified by the student as outliers, or erroneous readings, or erroneous measurement , simply based on his/hers judgment, based on the other measurement taken
Average measurement	This is calculated by the VLE, showing the student the average value of the measurements selected/accepted by the student
Student Comments	This is an open ended section, where students commented on the experience with the VLE, and if they had any comments, remarks, or over all evaluation

Table 2. Illustration of the student work and choices

Initial findings show that students were very excited to use the prototype VLE, found it easy-to-use and very useful. Below we report a few key observations and comments made by the students:
"*…the tool is very valuable as it simulates a real world exercise, in realistic settings; …it allows for control over all the equipment and the full processes and procedures required to perform the task..; it stimulated me to think ahead every step of the procedures in order to complete the activities; this software can be useful in order to prepare for exams and practice prior to going out to the field to perform the labs…; it can substitute practice on bad weather days when practice cannot be performed in the field…."*

In addition, the prototype proved to be a very effective instrument for assessing each student's knowledge of chaining concepts and practices versus the current methods. Presently, assessing individual student performance is a challenge mainly due to the fact that students work in teams.

5. CONCLUSION AND FUTURE WORK

In this paper we have described the development of a prototype VLE for surveying instruction, and we have reported the findings of an initial evaluation with a group of 27 undergraduate students. Evaluation results support our hypothesis that the fully developed VLE will be able to enhance the quality of surveying instruction by solving many of the problems associated with traditional teaching methods, and will appeal to the current generation of students who live in an information age where technology is an intrinsic and ubiquitous part of how we live and learn. Future work will involve the refinement and extension of the prototype. The fully developed VLE will include 5 educational modules which will cover fundamental surveying concepts and practices including Basic Surveying Math, Chaining, Differential Leveling, Triangulations and Coordinate calculations, and Current technologies in surveying.

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