Advances in Engineering Education

VOLUME 4 NUMBER 1 – WINTER 2014

An Interactive Virtual Environment for Learning Differential Leveling: Development and Initial Findings

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ABSTRACT

We describe the design, development and initial evaluation of an interactive virtual environment whose objective is to help undergraduate students learn and review the concepts and practices of differential leveling. The virtual environment, which includes realistic terrains and leveling instruments that look, operate, and produce results comparable to the physical ones, is not meant to replace field practice completely. It will be integrated in surveying courses as a preparation, revision and assessment tool. Initial findings from a formative study with sixty (60) undergraduate students and three (3) faculty show that the virtual environment is usable, engaging and useful for teaching/learning differential leveling. Results of a summative study with forty-eight (48) undergraduate students show that using the virtual environment led to an increase in subjects' declarative knowledge by 28% and procedural knowledge by 30%. Compared to traditional practice in the field, interacting with the virtual environment led to significantly higher declarative knowledge gains; differences in procedural knowledge gains (e.g. the ability to perform the leveling exercise in the field) between students who used the virtual environment versus students who had practiced in the field were not significant.

Key Words: Virtual Learning Environments; Differential Leveling; Surveying Education; Formative Evaluation

INTRODUCTION

The objective of the work reported in the paper was to develop and evaluate a virtual environment for teaching/learning differential leveling concepts and practices. Differential leveling is one of the main topics covered in undergraduate surveying courses; in general, during lecture the students learn fundamental principles of differential leveling, best practices to minimize errors and improve precision and accuracy, and finally evaluate and distribute the errors. In the lab students are introduced to leveling equipment and are given hands-on tasks to demonstrate proficiency at operating the instruments, accurately reading the measurements and correctly recording the data. Traditional methods for teaching differential leveling present several limitations. For instance, students work in teams and therefore it is difficult for the instructor to accurately assess the performance of each individual student; the ability to practice in the field is greatly affected by weather and lighting conditions; the number of terrains on which to practice is usually limited to the terrains that are available on the university campus; the students' ability to repeat assignments and further practice with the equipment is limited by the availability of the instruments.

The tool described in the paper overcomes many of these limitations. It provides students with an opportunity to practice the concepts and procedures of leveling independently from team members; it allows students to practice regardless of weather or lighting conditions; it gives them the possibility to perform assignments in a variety of virtual terrains, thus breaking the monotony of redoing the same exercise in the limited available space; it enables the students to repeat the assignments as many times as they need. Our virtual learning environment (VLE) includes realistic terrains and instruments that look, operate and produce results comparable to the physical ones. Furthermore, it is true to traditional surveying practices, as it requires the students to perform the same essential steps that are involved in a leveling exercise in the field.

Evaluation of the VLE includes two forms of assessment: formative and summative. In this paper we describe the design and development of the software tool and report the findings of an initial formative study with faculty and students and a summative study with students. The paper is organized as follows: in section 2 we discuss the benefits of virtual learning environments (VLE) and report prior work on VLE for engineering and surveying education. In section 3 we explain principles and practices of differential leveling and describe our VLE. In section 4 we report the findings of the two studies; conclusions and future work are included in section 5.

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 [1]. 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 [2; 3; 4]. Research also shows that Virtual Reality (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 [5].

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 [6; 7; 8; 9; 10; 11]. 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 [12]. 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 [13; 14]. 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 [15], some researchers argue that Virtual Reality is mature enough to be used for enhancing communication of ideas and concepts, stimulate the interest of engineering students and improve learning [16]. Some noticeable examples of engineering virtual laboratories exist. For instance, Del Alamo [17], a professor of electrical engineering at MIT, created a web-based microelectronics lab for his students in 1998. At Johns Hopkins University, Karweit [18] simulated various engineering and science laboratories on the web. At the University of Illinois Urbana-Champaign (UIUC), researchers developed a virtual laboratory for earthquake engineering [19]. At Purdue University, Richardson and Adamo-Villani [20] developed a photorealistic 3D computer-simulated laboratory for undergraduate instruction in microcontroller technology.

In the area of surveying, Kuo et al. [21] 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. [22] 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 [23] 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. At Purdue University, Dib and Adamo-Villani [24; 25] have developed a virtual learning environment for teaching and learning the surveying concept of chaining. A pilot study with a group of undergraduate students showed that subjects found the application effective for learning surveying concepts and practices and for getting feedback on their understanding of the subject.

Although some authors have documented that VR experiences provide advantages over more traditional instructional methods [26; 27], studies of VR projects are still relatively rare and a need exists for investigations of VR in the undergraduate classroom [12].

THE VIRTUAL LEARNING ENVIRONMENT

Differential Leveling

Differential leveling is the practice of measuring the height differences between a series of points of interests and/or the elevation of a point in relation to mean sea level. To perform a differential leveling exercise, students set up a level on a tripod and level it so that the line of sight is horizontal. A graduated rod is held vertically over the first point of interest and a reading made of the intersection of the cross-hair with the image of the rod (backsight - b). The same (or an identical) rod is then held vertically over the second point and a further reading made (foresight - f). The difference between the two readings is the difference in height between the two points:

$$\partial h = b - f$$

If b is greater than f then ∂h is positive (i.e. there is a rise in elevation in moving from the first to the second point). "*This process can be repeated - the level can be moved to beyond the second* *point and the height difference between the second and a third point measured by the same process. Further repetitions will allow the height difference between widely separated points to be determined by accumulating the height differences between intermediate points. The distance from level to rod is dictated by the steepness of the terrain and the clarity of the image viewed by the observer. Usually the maximum sight length is restricted to 50-60m.*" [28].

In plane surveying the area in which the user is working is limited and is very small compared to the radius of the earth; within this context the horizontal line/plane and the level line/plane are practically the same as the two are tangent to each other and both are perpendicular to the vertical line. In this limited space the measurements of the elevation of the points in relation to each other and to the mean sea level is usually biased because of instrument errors, user errors and optical errors (e.g. the refraction of the instruments due to the conditions within the working environment). Therefore the main challenge of the user is to minimize and manage the error by understanding the limitation of the instruments and the environment in which the leveling exercise is conducted.

VLE Educational Content and Interaction Design

In the VLE, the students have the option to select from a database of terrains that vary in topography, vegetation, and obstacles. Once the terrain is selected the students have to exercise their good judgment on where to locate the tripod and the level in order to maximize access to the points of interest. The selected location of the level has great impact on the ability to complete the leveling exercise with accuracy and speed. A good placement of the level leads to more points measured from one single set up location, therefore less time to complete the exercise and less room for errors. Figure 1 - A shows the selected terrain and the placement of the level.

After placing the instrument, the student needs to calibrate the level so it is plumb. If the level is not plumb the instrument does not measure the horizontal line, and this results into failure of the exercise. In the field the student works with the leveling screws in order to get the instrument to be correct and plumb. The rule in the field is that the air bubble follows the left thumb: when the student rotates the screw with his/her left thumb the air bubble moves in the same direction as his/her left thumb, i.e. if the operator turns counterclockwise with the left thumb the air bubble will move away from the rotating screw; if the operator turns the screw clockwise with the left thumb the air bubble will move closer to the rotating screw. In the VLE, this process is truly represented as the student is presented with a visualization of the leveling screws and he/she uses the mouse to rotate the leveling screws in order to level the instrument Figure 1-B. The instrument is considered plumb once the air bubble settles in the center. In the field the instrument has an optimal range beyond which the measurements are not accurate; this is limited by the optics of the level. Similarly, in the VLE the instrument range is limited to 200 feet as an optimal measuring distance. The student should select

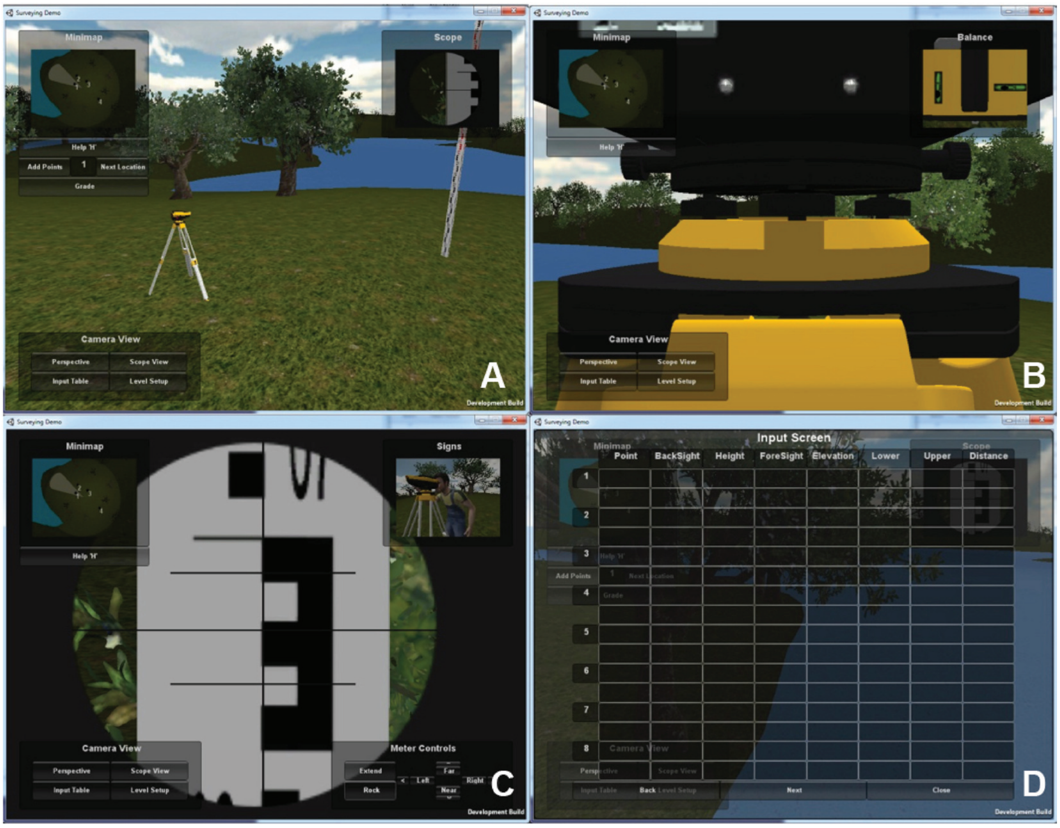

Figure 1. Screenshots of the virtual environment. Perspective view of the environment and placement of level and rods (A); level setup (B); scope view (C); input table (D).

points within this lighted area in order to avoid a situation in which the measuring rod is out of the range of the level. This could cause erroneous readings, hence leading to increased chance for errors. As in the field, the next step for the student is to place the measuring rods on the various points of interest and record the readings on the rods (Figure 1 - C) in the table (Figure 1 - D). An accurate reading of the measurement will require the student to signal to the rod person directions to rock the rod, a common practice in the surveying field whose intent is to record the lowest measurement. The communication between the instrument person and the rod person is done via hand signal (in the case of the VLE no other student is involved in the process, thus the same student plays both roles). The character representing the student in the virtual environment gestures the corresponding hand signal based on the desired command. This practice is true to real practices in the field, where the students communicate via hand signals with the team members. Figure 2 shows the 3D character representing the student/construction worker making a variety of hand signals used in surveying.

Figure 2. Six hand signs used in surveying: Move to the left 1/8" (1); Lower the rod (2); Move to the right 1" (3); Move forward (4); Raise the rod (5); Top (6).

Finally, the measurements are recorded in tabular format, as in surveying practices in the field. In the VLE, the student is required to record the measurements in the appropriate cells in the provided table (Figure 1- D); failure to record the measurement appropriately will result in failure of the exercise. The VLE captures the best industry practices and offers the students an opportunity to iterate and practice these best behaviors to improve accuracy and precision when doing the work in real world settings. A video demonstration of the VLE is available at: https://www.youtube.com/watch?v=-jTYq_rOftc&index=3&list=PL84VcUp5xaBsRutUS-8KR2lwFxh8KfI9G

Technical Implementation

Some of the key features of the VLE include: (1) *Open content*-- the VLE has an open architecture that supports flexible customization; educators will be able to easily modify existing content. (2) *DEM (Digital Elevation Model) data support*-- the VLE supports import of DEM data and allows

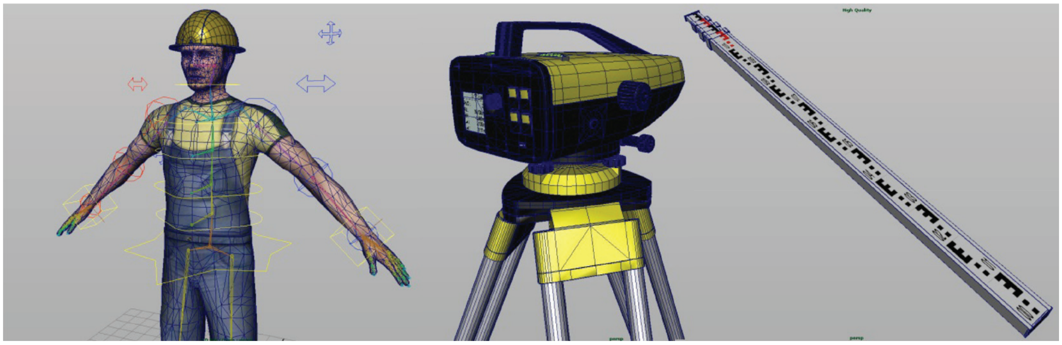

Figure 3. From the left: 3D model and rig of the construction worker; 3D model of the level instrument; 3D model of the rod.

for real-time generation of 3D terrains based on these data. This feature provides students with a large selection of terrains they can practice on. (3) *Tracking of user performance*-- quantitative data related to students' performance is recorded automatically when the software is used and is forwarded via internet to a central database on the project's server where it can be accessed by the course instructor and evaluator. For instance, data include students' answers to problems, number of attempts required to perform a particular task, time spent on it, etc. The software also records user interface traces that allow play back of actual user interface manipulations (cursor trajectory, buttons clicked, text entry, menu selections). These data are being used to iteratively refine the design and usability of the VLE.

The platform for the project is based on Unity 3D and Autodesk Maya software. We used Maya software to model, texture and animate the virtual instruments and characters (Figure 3 shows the 3D polygonal models of the construction worker character, level and rod). Interactivity with the 3D components was programmed in Java script using the Unity game development platform. The choice of Unity platform was based on the following considerations:

- Unity has an optimized graphics pipeline that supports interactive rendering of complex animated 3D meshes and advanced lighting and textures even on computers with limited graphics capabilities.
- Unity interfaces seamlessly with major 3D animation tools (i.e. Autodesk Maya and 3D Studio Max) and file formats, and allows for instantaneous import and update of asset files and animations.
- It supports a wide range of publishing platforms, including: standalone builds for Mac OS and Windows; web delivery through the Unity Web Player Plug-in; Wii and Iphone publishing.

The VLE is designed to run on hardware and software infrastructure that is already widely deployed in universities and students can use the VLE on low-end personal computers (PC/MAC) with low-end graphics cards. Different strategies were used in order to optimize VLE performance. Geometric complexity of the 3D models was kept at a minimum, while retaining visual quality, to ensure client hardware can run the application at interactive rates. Normal maps, a technique for simulating complex geometric detail, was used to add fine detail to objects without adding extra geometry. Level of detail was also employed to find an accurate balance between performance and visual quality on the client machine. Furthermore, light maps were implemented to provide high quality lighting for static geometry without impacting performance.

EVALUATION

Assessment of the VLE includes two forms of evaluation: formative and summative. Formative evaluation focuses on the design features of the VLE (i.e., usability, user engagement and quality of the graphics); summative evaluation tests the efficacy of using the VLE for learning differential leveling principles and practices. In section 4.1 we describe an initial formative evaluation of the VLE with undergraduate students and faculty; in section 4.2 we describe a small-scale summative study with undergraduate students.

Formative Evaluation

The goal of the formative study was to answer the following questions: (1) is the VLE usable, and engaging, (2) do students find the VLE useful for learning/reviewing differential leveling concepts and practices, (3) do faculty find the VLE useful for teaching differential leveling and would they be willing to use it in their classes, (4) how can the VLE be improved.

Study Design

The study collected quantitative and qualitative data. Quantitative data included time spent on the leveling exercise in the VLE, completion/non completion of the VLE activity, and participants' answers to a survey with rating questions pertaining to the usability and perceived usefulness of the VLE. Answers were based on a 5-point Likert scale ranging from strongly agree to strongly disagree.

Qualitative data included observation, 'think aloud protocol' and 'critical incidents', i.e. problems encountered that affect task flow and performance, and answers to open-ended questions. This study was a quasi-experiment, where the sample population was pre-selected. Subjects were recruited randomly from classes and programs at Purdue University; participation in the study was voluntary.

Subjects

Sixty (60) undergraduate students age 19-22 years old enrolled in Building Construction Management in the College of Technology at Purdue University. Two out of sixty (2/60) subjects were females. Three (3) faculty from the Building Construction Management Department in the College of Technology at Purdue University.

Procedure

Testing was performed in a controlled lab setting. Each participant was directed to sit in front of a laptop with an external mouse device attached. Each subject began the test by answering demographic questions via a survey. Upon completion, each participant was asked to read the online instructions and then was instructed to open the executable of the VLE and complete the differential leveling exercise. A demonstration of the tool was conducted in front of the students and projected in the room on a big screen prior to the beginning of the testing exercise. Subjects were introduced to the functionality of the tool and familiarized themselves with the VLE user interface. Participants were allowed to interact with the VLE for a maximum of one hour and thirty minutes. After completion or failure of the leveling exercise, each participant received a grade and a detailed performance report. Finally, subjects were asked to refer back to the survey to answer questions about the VLE and overall experience.

Findings

VLE Metrics. The mean time spent on the leveling exercise was 50′:40″ (minutes:seconds); the maximum time spent interacting with the VLE was 75′:25″; the minimum was 35′:55″. All subjects were able to complete the activity.

Answers to Rating Questions. Overall, participants found the VLE an effective learning tool (Mean = 1.9; strongly agree = 1 and strongly disagree = 5) and easy to use (Mean = 2.8; strongly agree = 1 and strongly disagree = 5). Participants thought the VLE provides good surveying practice (Mean = 1.9; strongly agree = 1 and strongly disagree = 5) and their reaction to the quality of graphics (i.e. realism of the terrains and fidelity of the instruments and animations) was positive (mean = 1.4; strongly agree = 1 and strongly disagree = 5). Participants' perception of the precision of the instruments was positive as well (mean = 1.4; strongly agree = 1 and strongly disagree=5). When asked if they were to recommend the VLE in future surveying classes, the subjects' response was encouraging (Mean = 1.9; strongly agree = 1 and strongly disagree = 5).

Answers to Open Ended Questions. Answers to open ended questions show that some subjects found difficulties navigating the virtual environment as the camera movements and path are mainly in flying motion and are not attached to the level and/or at the eye level of the character. Some students felt that having a video tutorial that would elaborate on the controls and commands in the environment would be helpful; they also felt the information provided in the help menu was not sufficient. Some students suggested that an exercise where they are provided with a set of fixed points to set up the instrument on and set points to measure would be a good starting exercise before taking on random points within the environment. Responses regarding the most fun aspect of the VLE predominately pointed to the graphics.

All three faculty commented that the VLE is a useful resource for practice and revision of surveying concepts and practices, and assessment of students' performance. One faculty thought that the VLE cannot fully replace the real world exercise and should be used as a revision and assessment tool. Two faculty thought that the VLE could be used to provide surveying training at distance. One faculty commented: "*Students who rely on distance learning or are enrolled in programs at smaller/satellite campuses. . .* (these smaller campuses usually cannot afford to buy the surveying equipment) *are currently deprived of opportunities to practice with the instruments and have to make several trips to the main campus during the semester in order to learn best surveying practices. The VLE can provide these students with great hands-on surveying practice and limit their trips to the main campus*".

Observation. Observation and subjects' comments showed that the majority of the participants were engaged and focused while interacting with the VLE. Initially, participants appeared confused about the application functionality and user interface but acquired confidence as they progressed with the exercise. Although they expressed signs of frustration with the user interface controls, they appeared to be challenged and eager to complete the exercise correctly. The majority of the participants interacted with the VLE using a trial and error approach even though they had read the instructions and watched the demonstration. We believe that this trial and error approach used by the majority of the subjects had a significant impact on completion time.

Summative Evaluation

The goal of the summative evaluation was to provide an indication of whether using the VLE affects students' learning of differential leveling concepts and practices. Learning is a multidimensional construct that includes cognitive, metacognitive, and motivational components [29]. Our experimental study focused on the cognitive aspects, e.g., descriptive (or declarative) knowledge, or the ability to memorize and recall information, and procedural knowledge, or the ability to apply acquired knowledge to perform specific tasks [30]. In particular, the study aimed to assess the influence of the VLE on student ability to: (1) demonstrate knowledge and understanding of fundamental leveling concepts, terminology and procedures, and (2) correctly perform a leveling exercise in the field (e.g., set up location properly, mark the points and benchmarks, set up the instruments correctly, take and record measurements, calculate error, and distribute error). We measured these two learning goals using pre and post educational intervention competency testing. The testing instrument included a written test comprised of fifteen questions that assessed students' declarative knowledge, and a lab practical to be performed in the field. The pre-test and post-test were identical.

Subjects

Forty-eight (48) undergraduate students from the Building Construction Management (BCM) department at Purdue University.

Procedure

All students received a forty-five-minute lecture and a forty-five-minute lab demonstration on differential leveling. During lecture, students were introduced to basic differential leveling concepts, definitions of terminology (level lines, horizontal lines, vertical lines, bench marks, back-sight, fore-sight, horizontal plane, level plane), differential leveling methods, error calculation and distribution of error. In the lab, students were introduced to leveling equipment, were given a basic demonstration on how to operate the instruments, and were shown how to read the measurements accurately and record the data correctly. After the lecture and lab demo, the students were administered a pre-test. The pre-test included a written test (to assess declarative knowledge) and a leveling exercise in the field. After the pre-test, a randomized complete block design was used to divide the subjects into two groups with similar pre-knowledge. In other words, we used the pre-test scores to group individuals in terms of pre-knowledge and then made sure these groups of individuals were equally assigned to the two intervention groups, e.g. group A (control group), traditional practice in the field, versus group B (experimental group), VLE.

Two weeks after the pre-test, group A (control) worked in the field for one hour practicing differential leveling with the help of one of the instructors; group B (experimental) worked in the lab for one hour using the VLE. Another instructor was present in the lab to address possible technical problems with the software; all subjects in group B were familiar with the VLE user interface. Both groups were tested for differential leveling competency after the two educational interventions (VLE versus traditional field practice). The post-test was the same as the pre-test. The difference in scores between the pre and post test provided an indication of (1) whether using the VLE improves learning of differential leveling concepts and practices; (2) whether using the VLE leads to greater learning gains than traditional practice in the field; and (3) which aspects of learning (declarative knowledge versus procedural knowledge) benefit the most from using the VLE.

Findings and Discussion

Results show that using the VLE led to an increase in subjects' content learning by 29%. In particular, students who used the VLE increased their declarative knowledge by 28% and procedural

	Group A (control)			Group B (experimental)		
	Pre-test	Post-test	Improvement	Pre-test	Post-test	Improvement
Mean score on Declarative Knowledge part	71.34	84.92	19%	70.26	89.81	28%
Mean score on Procedural Knowledge part	67.57	89.66	32%	66.31	86.25	30%
Mean total score	69.45	87.29	26%	68.28	88.03	29%

Table 1. Mean scores for pre and post-tests and mean learning gains for Groups A and B.

knowledge by 30%. Findings also show that there are differences in learning gains between Group A and Group B. Overall, using the VLE led to higher learning gains than traditional practice in the field (29% versus 26%). More specifically, using the VLE lead to higher gains in declarative knowledge (28% versus 19%) but slightly lower gains in procedural knowledge (30% versus 32%). Table 1 shows a summary of the results.

Three 2-sample t-tests were performed to determine if the difference in total learning gains, the difference in declarative knowledge gains and the difference in procedural knowledge gains between the control and experimental group were statistically significant. Results of the statistical analysis show that the difference in total learning gains between the control and the experimental group *is not statistically significant* (M = 25.97(group A); M = 29.02(group B); STD = 6.42(group A); STD = 5.78(group B); P-value = 0.064); the difference in declarative knowledge gains *is statistically significant* (M = 19.32(group A); M = 30.11(group B); STD = 7.13(group A); STD = 6.84(group B); P-value = 0.035); the difference in procedural knowledge gains *is not statistically significant* (M = 32.34(group A); M = 29.46(group B); STD = 6.41(group A); STD = 5.94(group B); P-value = 0.095).

Overall, these findings suggest that the VLE has potential for being an effective learning tool. The statistically significant difference in declarative knowledge gains between the two groups demonstrates that performing differential leveling tasks in the VLE helps students improve their understanding of fundamental leveling concepts/ terminology more than practice in the field. The small difference in procedural learning gains between group A and group B (not statistically significant) suggests that the efficacy of the VLE for learning differential leveling practices is comparable to that of traditional practice in the field. Although the VLE is not meant to replace field practice, findings of this study demonstrate that it can provide students with effective hands-on surveying practice to prepare them for real-world differential leveling tasks in the field.

One limitation of this study was the small sample size. An ideal sample population, calculated using an online power/sample calculator, would require at least 60 subjects. Because of the limited number of participants we cannot generalize the results and we can only claim that the VLE shows promise of being an effective instructional tool. The intention of this small scale empirical study was to provide preliminary evidence that will lead to a more rigorous evaluation of the effectiveness of the VLE with a larger sample population in future research.

CONCLUSION AND FUTURE WORK

In this paper we have described the development and initial evaluation of a virtual learning environment whose goal is to augment the teaching of differential leveling principles and practices to undergraduate students enrolled in surveying courses. One of the goals of our research is to provide a demonstration that certain topics in surveying can be taught as or more effectively using virtual learning environments than by traditional methods. Findings from a formative study with students and faculty showed that the VLE was perceived as easy to use and useful for learning differential leveling principles and practices. An experimental study of the influence of the VLE on students' content learning provided preliminary evidence of the effectiveness of the VLE as a learning tool. Using the VLE led to an increase in subjects' declarative knowledge as well as subjects' procedural knowledge. Compared to practice in the field, using the VLE lead to significantly greater declarative knowledge gains, while gains in procedural knowledge were slightly lower, but not significantly different.

The VLE for learning differential leveling is part of a larger project whose goal is to develop and evaluate a surveying application that includes four educational modules (chaining, differential leveling, triangulations and coordinate calculations, robots and GPS equipment). This research and development project, sponsored by the National Science Foundation (NSF-TUES), addresses the need to create innovative learning environments that incorporate the best of traditional pedagogy with new paradigms that reflect our times (our students live in an information age where technology is an intrinsic and ubiquitous part of how we live and learn). The project's long-term goal is to use emerging computer graphics technologies to develop and validate innovative educational technologies that support students learning and lead to effective instructional approaches in the engineering and technology curricula.

Provided that our work is successful, expanding the VLE approach to other surveying concepts as well as other subject domains seems to be a logical step in which to proceed. If we are able to show a correlation between the VLE and student attitudes and performance in the classes in which it is used, we expect to expand the tasks to other civil engineering/building construction management courses, as well as broadening usage in the target classes.

ACKNOWLEDGEMENTS

This research is supported by the National Science Foundation (NSF) – TUES program, award # 1140514 (June 2012 - Dec. 2014).

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