A Study of Engineering Students Interaction with Distributed Virtual Reality in the Classroom

Tulio Sulbaran[1] and Nelson Baker[2]

Abstract

The study reported in this paper focuses on key issues that could impact the extensive use of Distributed Virtual Reality (DVR) in the classroom. The key issues studied are: learner aptitude towards reading/following instructions in DVR, student capability to navigate in DVR, learner interaction with the DVR, learner appraisal of the DVR's responsiveness, DVR capability to transfer knowledge, and learner engagement and acceptance of DVR. The study was conducted in engineering classrooms and the students were given the opportunity to interact with DVR during class time. The result suggests that the use of DVR in engineering classrooms has a high potential to positively impact engineering education. This is important because DVR media can provide the engineering community with an innovative and powerful approach for enhancing the delivery engineering content.

Mismatch in Engineering Education

Engineering education is facing a challenging situation, which is reflected not only in the universities but also in the work place. In a study done by Astin, with nearly 25,000 students over 300 institutes, it was found that approximately 43% of first year engineering students completed their degree in engineering [A. Astin]. Furthermore, in comparison with majors in other fields, engineering majors are much more dissatisfied with the quality of instruction they receive in college and with their overall college experience [A. Astin]. Issues regarding engineering education go beyond the university level. A study performed by the National Society of Professional Engineering (NSPE) showed that students are unprepared for many necessary job skills such as problem definition and decision-making [NSPE].

Explanations for this situation facing engineering education seems to involve a puzzling set of factors, and among these factors is student attitude. This attitude toward engineering is most likely related to the instructional environment, which in turn could be related with the match or mismatch between student learning preferences and the media used to teach engineering. Felder indicates that the mismatches between the prevailing teaching style in most science courses and the learning styles of most students have several serious consequences [R. Felder]. Godleski also supports such an idea by saying that students who experience a learning/teaching mismatch feel as if the are being addressed in an unfamiliar foreign

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language: they tend to get lower grades than students whose learning styles are better matched to the instructor's teaching style [Godleski]. Furthermore, students who experience learning/teaching mismatch are less likely to develop an interest in the course material [Felder]. A common mismatch is exemplified by the fact that the majority of university classes have very little visual information and students are primarily listening to lectures and reading material written on chalkboard, in textbooks and handouts. Unfortunately, most engineering students and practitioners are visual learners, which means that most students do not get nearly as much as they would if more visual presentation were used in class [Felder].

Most engineering students are visual rather than verbal learners. Visual learners retain better what they see (pictures, diagrams and others) while verbal learners get more from words (written or spoken explanations). It is also important to highlight that a study performed by Nelson showed that those students who received instruction congruently with their learning style preferences achieved significantly better [Nelson]. Therefore, the authors are driven by the idea that the incorporation of visual information, provided by virtual reality environments would greatly impact how material is delivered and how it is received.

Virtual Reality as Mismatch Mitigation

The use of visual cues provided by Virtual Reality (VR) could transform the way engineering is performed, both in learning new material and in terms of explaining activities between practicing professionals. A more visual teaching style could better match the students preferred learning style. VR capability can be augmented by using the Internet as a distribution channel. When VR is delivered via the Internet, it is called Distributed Virtual Reality (DVR). DVR provides the students with scenarios that allow them to actively participate in the learning process by seeing, hearing and interacting. DVR allows the engineering students to experiment with their own ideas and see the results of their changes through a meaningful display. Furthermore, with the help of the Internet, the learning environment overcomes the traditional geographical limits of school and platform dependency.

The authors think that the use of DVR in the engineering classroom will enhance transfer and retention as well as increase student engagement. DVR will give the engineering community a novel teaching tool, which can be implemented without requiring unusual classroom resources and that could be refined and improved in a collaborative effort among many participants. It is also expected that this type of tool would play an active role in the education of future engineering students.

The work presented here shows the development and assessment of one DVR study for engineering classrooms. The information obtained from this study leads to a better understanding of DVR for engineering education. The lessons gained will help the development and implementation of DVR for engineering subjects in a variety of university settings.

Development and Implementation

The technology available for the development and implementation of DVR is advancing much faster than the advantages taken by the engineering community for such capabilities. Today's engineering students are growing up in a video game and Internet era. The Internet is more accessible to more students in more universities all around the world. Thus, there is an enormous interest in developing teaching tools that can be used through the Internet. These tools have evolved from text through 2D graphics and now move toward 3D interfaces. This reflects the ongoing evolution aimed to a human-centered interface design that is toward a more immersive and responsive computer experience. DVR experiences merge the intuitive human sense of space and time with an easy learner interface, creating a novel and exciting technology for engineering education.

Below, the authors provide a brief overview of DVR technology available and the DVR tool developed for the experiment. The authors will also summarize the criteria taken into consideration for the development of the survey tool and provide the results of the study.

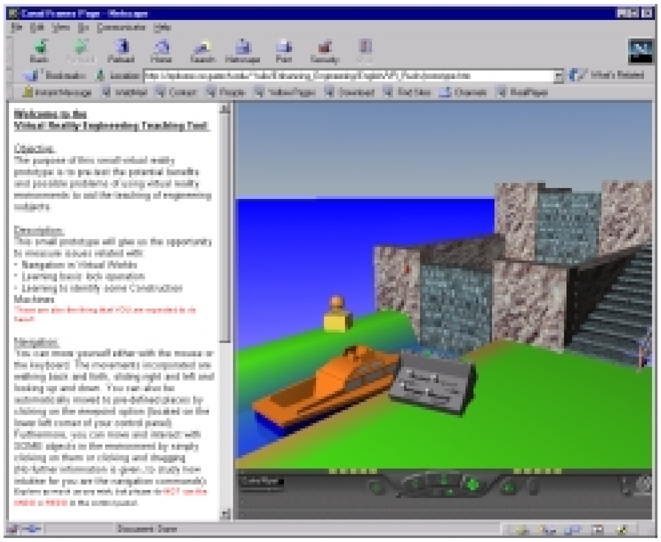
Developing the Virtual Environment

The immersion of the user into a 3D virtual world of computer generated objects, known as Virtual Reality (VR) is growing very fast. In this growing process, VR has been integrated with the WWW revitalizing the idea of DVR. The idea of DVR has existed for many years, however is not until now with the development in computing and networking performance through the 90s that the infrastructure is available. One of the most commonly used languages to create DVR is VRML. VRML was approved as an International Standard by the International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) in December 1997. As "Hypertext Markup Language (HTML) led to a population explosion on the Internet by implementing a graphical interface, VRML adds the next level of interaction, structured graphics, and extra dimensions (depth and time) to the online experience as well as spatialised sound, interaction, navigation and behavior" [Sulbaran].

Internet browsers such as Netscape and Internet Explorer support 3D content by using plugins. There are several VRML plugins available, two of the most popular are WorldView by Intervista [Intervista] and Cosmo Player by Silicon Graphics[SGI]. There is no constraint for using a particular plugin with a particular web browser and the plugins can be download for free from the Internet. "It is anticipated that, over time, the display of 3D content will become integrated into the main browser display. In fact, some of today's 3D browsers display 2D content as 2D objects within a 3D world" [Sun].

VRML was used to develop the DVR for this study. The DVR is also consistent with current pedagogy and today's (or near future) computation capabilities. The main criteria used during the creation of the DVR were: navigation, latency, user characteristics, preferences and expectations (for extensive discussion on criteria please refer to "Enhancing Engineering Education through Distributed Virtual Reality " by T. Sulbaran and N. Baker, FIE 2000). Using these criteria, the main focus of the developed DVR was to measure key issues that could impact the extensive use of DVR in the classroom. The key issues studied are: learner aptitude towards reading/following instructions in DVR, student capability to navigate in DVR, learner interaction with the DVR, learner appraisal of the DVR's responsiveness, DVR capability to transfer knowledge, and learner engagement and acceptance of DVR. The authors also recognize that methodologies for using DVRs in engineering teaching have not been defined, and the hardware and software used for DVRs have much room for improvement.

Two DVR prototypes were created. One prototype teaches how a lock along a waterway operates (See figure 1), and the learner's objective is to be able to operate a lock through the control panel (See figure 2). The focus of this application is on the 'How', thus corresponding to the analysis level of Bloom's Taxonomy [Bloom]. The other DVR created shows construction equipment such as that shown in figure 3 and the learner's objective is to be able to identify a variety of construction equipment. Thus, this DVR focuses on the identification level of Bloom's taxonomy [Bloom]. Both DVR environments are interconnected by transports (similar to hyperlink in web pages) that allow students to move from one virtual world to another (see figure 4).



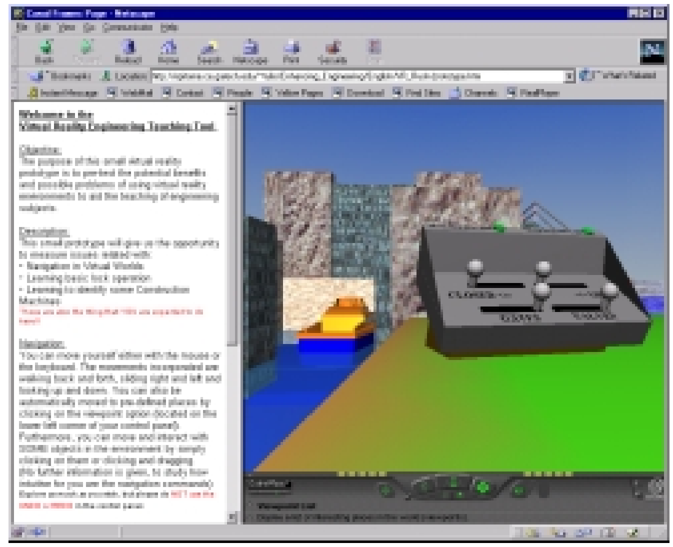
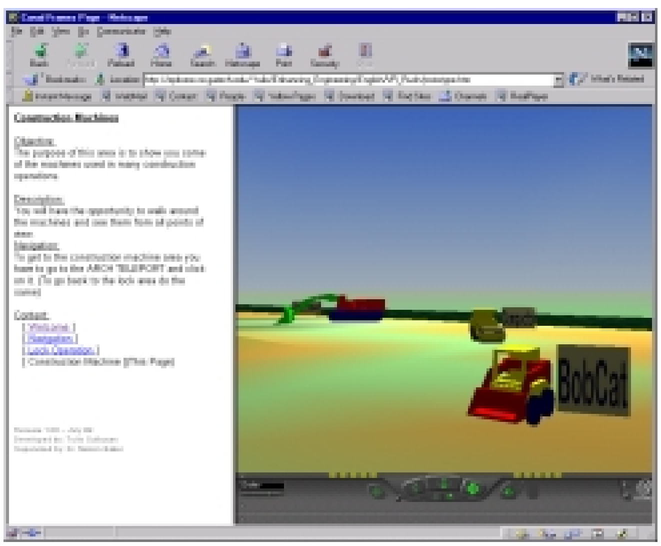


Figure 1. DVR: How a lock along a waterway operates. Figure 2. DVR: Control panel for the lock



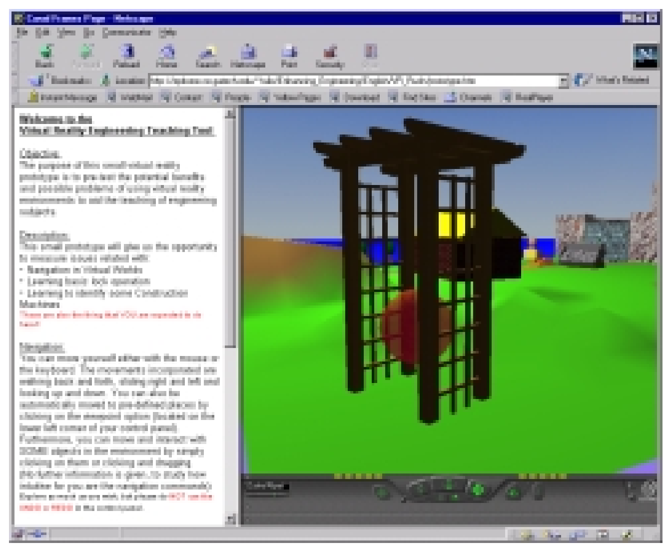


Figure 3. DVR: Construction Equipment
. (Bobcat)

Figure 4. DVR: Transport to interconnect DVRs

Developing the Survey

A survey was prepared to assess the previously mentioned issues. “The proper design of questionnaires for scholarly research is a difficult and complex procedure” [Allen]. There are many good references on survey and assessment, however the one that most influenced the preparation of the survey developed to assess the DVR was “Designing and Conducting Survey Research, by Rea, L., Parker, R. Jossey-Bass Publishers, 1997”. In here, instead of providing all the details of survey preparation, the authors will highlight the most relevant characteristics with the intent to showcase the engineering aspect of the assessment.

An issue that should be taken into account during survey development is its length. The longer the survey, the less willing the responder will be to provide information or even worse, the answers can be affected. For this reason all surveys in this research are limited to 15 minutes and in most cases less than 10 minutes. Another interesting aspect is the number of pages, which plays an important psychological effect, because people tend to think that less pages implies faster completion of the survey. This may not be true, but the illusion can be achieved in many different ways, for instance in our survey the options for multiple choice or true/false questions were listed across rather than vertical (see figure 5).

Many studies demand that extensive demographic information be included, however in our study demographic questions were reduced to a minimum to be able to concentrate on the measure of the DVR issue previously mentioned. Standard questions such as marital status and salary were considered not readily related to the research and were dropped from the questionnaire.

An interesting fact about surveys is that some types of questions cause some students to answer reluctantly (for example grades). Thus, we used categories to group answers to reduce this resistance. Allen indicates that “The use of categories is actually beneficial, since it may be more useful to analyze data by groups than by specifics” [Allen]. Another very interesting fact is the “central-tendency” concept; that is; “the tendency of people to avoid taking an extreme stand and to choose the middle answer on a question” [Allen]. In order to avoid such situations in our surveys (see figure 6), we use even number of options for a given question (normally 4). With this approach the responses were driven to stay on one side or the other. We strongly rely on closed-end questions (questions that provide a fixed list of alternative responses). There are several advantages to this type of question. Some of the main advantages are easier comparisons among respondents, which simplifies the analysis process and tends to make the survey clearer. Some open-ended questions were utilized when the constraints of the closed-ended did not allow for them to be used, but the survey used these sparingly.

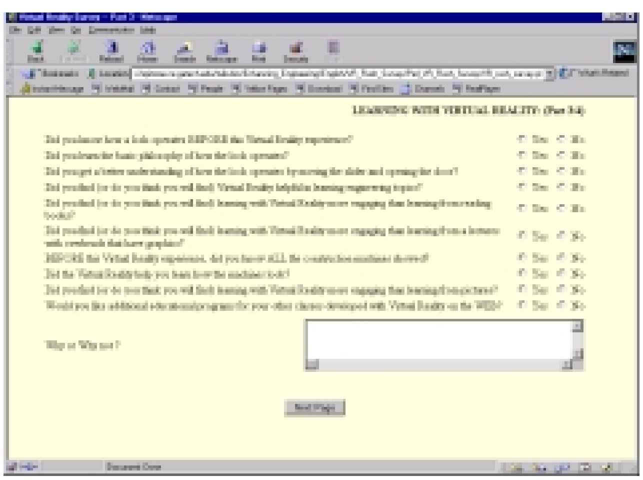


Figure 5. True/False question in survey
. (Option listed across rather than vertical)

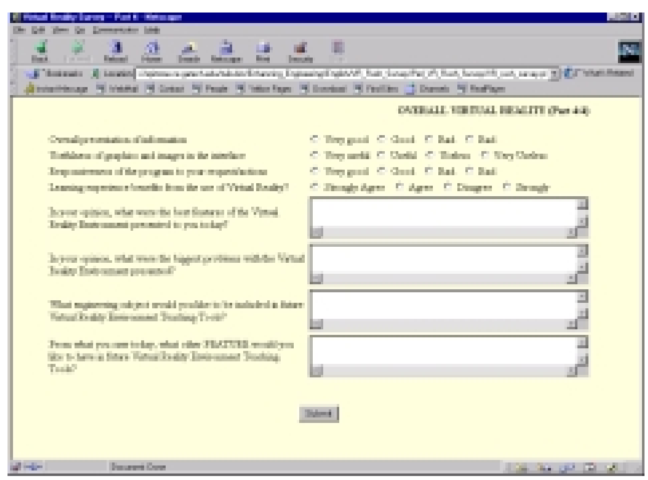


Figure 6. Multiple choice question in survey
(Even number of options)

The questions were also sequenced to ensure that they were placed in a logical succession and grouped to facilitate the learner's answers. Category titles were also used to aid the responders. Internal-consistency checks were not used, because they increase the length of the survey and they "cannot ensure reliable data" [Allen].

Finally, pre-testing the survey always plays an important role since it is a very useful way to screen the questionnaire before data-collection and increases the reliability and validity of the data. A very interesting point that we found during this research is that students and faculty react differently and it is very important that the survey pre-test be deployed not only to students but to faculty if the research is to be scholarly. The wording has to be simple, clear, straight forward, and brief.

Implementing in the Classroom

Our premise is not that DVR will replace the instructors, but instead augment them by providing a visual component to their teaching. DVR could prove to be a valuable alternative educational media to convey engineering knowledge and this work aims to provide additional insight. Although, as stated before, the DVR will not replace the instructor, to better measure the impact of the DVR tool, the DVR in this study was presented alone without explanation about the topic or the media.

The study was conducted at Georgia Institute of Technology and the participants were part of several sections in two courses. These two courses were 'CEE 4120 Construction Equipment and Methods' and 'CEE/ME 1770 Introduction to Engineering Graphics and Visualization'. CEE 4120 is a course mainly with CE majors in their junior and senior years. CEE/ME 1770 is a course with a variety of disciplines including AE, CE, ME and others. CEE/ME 1770 includes students from all class levels with a majority of students in their freshman and sophomore years. The experiment was performed in an university classroom using the technology available with no special equipment. The DVR model uses textures and shading for 3-D information. The rendering process was done by PC Intel II processors, 300 MHz processing speed and 64 Mb RAM, ATI graphics accelerator with 8MB and 15" monitors. The participants interacted with the environment using mice and/or keyboards and all students simultaneously ran the environment.

The instructor did not provide any guidelines on how to interact with the DVR, so learners followed their own intuition for interaction (probably gained on video games or other software). The learner did not receive any instruction on what should be done in the environment, so they have to rely entirely on the instructions embedded in the DVR. During the study, the tool was used as a standalone source of information. The instructor only indicated the URL where the tool was located and instructed the students to interact with the environment and follow the instructions displayed. All learners were instructed to ask a classmate if any problem arose. The objectives given to the students in the text portion of the screen were; navigate/interact in virtual worlds, learn how a lock operates, and learn to identify some construction machines. Other text information was presented during the lesson such as the steps to operate the lock.

The learner did not have a pre-established time constraint, but the average interaction time was between 17-22 minutes. The group was instructed to achieve the DVR objectives (described above) and then asked to complete a survey. The survey was also on-line and included forty-one questions. The questions were closed and open-ended questions as described previously. The engineering students filled out the questionnaire immediately after they completed the instructional lesson. It took about 10 to 15 minutes to finish the questionnaire. No control group and technology group was required because this study did not examine or compare different learning/teaching media.

A second paper-pencil survey was given to the students 7 to 21 days later. This survey was designed to measure the knowledge gained by the learner on lock operation and construction equipment. This survey was administered without previous warning to the students, so they did not have time to review the material before the survey. The students took 5 minutes to answer the 2 questions of the survey.

Outcomes from the Engineering Classrooms

Composition of the Groups

All the sections of each course were grouped together to form two-sub groups. This was done because student class year (FR, SO, JR, SR) were very different between the two classes.

The CEE 4120 sub-group was composed of 36 civil engineering students, 11% Junior and 89% Senior. The CEE/ME 1770 sub-group was composed of 206 engineering students, 13% of the students were freshman, 70% Sophomore, 16% Junior and 1% Seniors. Civil Engineering students represented 22% of the CEE/ME 1770 sub-group, Mechanical Engineering 60%, Aerospace Engineers 17% and other disciplines 1%.

Outcomes

The authors observed that students in all sections in both sub-groups worked in peer-groups solving problems without the need for instructor intervention. Furthermore, the students engaged in real tasks (operating a lock and walking around construction equipment). The DVR provided the engineering students with an excellent teaching tool, but more important has provided students with a tool that fosters their intrinsic motivation.

In relation to the learner's aptitude towards reading/following instructions in DVR; it was observed that when engineering students (from all years and majors) have the chance to use DVR, most of them prefer to interact directly with the environment without reading the instructions (such as general information, navigation issues, instructional objective, etc). Therefore, any attempt to provide text information has to be rigorously studied and weighted.

Results showed that students are very capable of navigating in DVR. 77% of the learners in the CEE/ME 1770 sub-group and 95% of the CEE 4120 sub-group found it easy or very easy to navigate (perhaps the video game era). This implies a very short and intuitive navigation learning process, letting the student focus on the content of the topic.

During the interaction with the DVR, most of the learners in both sub-groups found the human computer interface very intuitive (100% were able to interact). It is important to highlight that this was achieved without providing instruction of how to interact with the environment. The study revealed that 53% of the CEE/ME 1770 sub-group used only the mouse, 4% used only keyboard and 41% used both, and from those that used both (mouse and keyboard) there is an approximate equal preference for each device. Similar trends were found in the CEE 4120 sub-group. This is important, because it indicates that when preparing engineering teaching tools the interfaces should allow the learner to interact with both mouse and keyboard, giving the learner the option to choose. However, "it is also important to note that the different input devices provides features (speed, feed back, options) that will impact the performance of the user in the environment" [Sulbaran].

Due to the intensive rendering processes in DVR, the authors thought that latency between commands sent and executed could make the DVR interaction unusable and frustrating. However, the visual/readiness trade off taken into consideration during the DVR development paid off. In the CEE/ME 1770 sub-group 74% of the students found the responsiveness of the DVR to be very good or good and 97% of the CEE 4120 sub-group considered the same. This difference is not due to change in computer hardware. A thought to explain the difference is that this could be due to more patient students in a sub-group were the average age is a little bit higher. Furthermore, 90 % and 100% of the students in the CEE/ME1770 and CEE 4120 respectively found the graphics/image interface to be very useful or useful.

In the literature there is very little data about DVR's capability to transfer knowledge and this study did not go in depth in that area (the author's future work will focus on that). However, it was found that during the first survey in the CEE/ME 1770 sub-group, 69% of the students thought they had learned how a lock operates and 57% thought they had learned to identify construction machines. But in the second survey performed 7-21 days later given without notice and whose intent was to focus on knowledge transfer, we found that 92% of the students were able to operate a lock and identify construction machines. This result implies that virtual environments can be used successfully for engineering teaching. Furthermore, in the CEE/ME 1770 sub-group 91% and in the CEE 4120 sub-group 95% of the learners strongly agreed or agree that the learning experience benefits from the use of virtual reality. The advantages for students include the ability to participate actively in the learning process, the ability to observe independently, and the ready access to a community of learning.

One important issue in education, and therefore in education using DVR, is the learner's engagement and acceptance. For both sub-groups, DVR resulted in a very engaging learning environment. 82% of the students in the CEE/ME 1770 sub-group and 91% of the students in the CEE 4120 sub-group find (or think will find) learning with DVR more engaging than learning from reading books, lectures or overheads (containing graphics or pictures). It was also found that 84% of students in both groups would like to have additional educational programs with DVR. The CEE/ME1770 sub-group indicated concern about not providing clear objectives for the DVR. This could be because most students did not read the text portion of the environment at the beginning of the session. Another reason might be that the DVR was implemented with no teacher instructions and it was presented within an environment of different course context (lock operation and construction equipment in an introduction to engineering graphics and visualization course). This concern were not found in the CEE/ME 4120 sub-group.

Transferability to other settings

These DVR prototypes will be tested next year in an International setting with a multilingual platform. Although, the test has not yet been performed, it is expected that similar results will be obtained. The test part of this study can be accessed and replicated in any university connected to the Internet. It is also expected that other universities can develop other course content (using the same development language VRML or any other) and then share those courses. This will lead to a reduction of cost and fast growing catalog of courses available. It is recommended to gradually introduce DVR in courses and assess its impact. This assessment should then be used to improve the DVR teaching tool. As with other teaching tools, there is not a unique or pre-scribed approach to make such tools a success.

Summary

Engineering education is under great strain; students are dissatisfied with the education and industry thinks that students are unprepared. In addition, the mismatch between student learning preferences and instructor delivery is common at Universities, which leads to a lower student interest for the subject. Therefore, action should be taken in engineering education to remain competitive in a highly technological society.

This study contributes to a better understanding of how Distributed Virtual Reality (DVR) could be used in engineering classrooms. The results show that students were able to navigate in the environment with no difficulties. They were also able to interact within the environment and found the responsiveness of this type of environment appropriate. The students were also capable of learning from the system and showed high levels of engagement and acceptance. Also, DVR provides the engineering students with the opportunity to experiment with their own ideas and see the outcomes through a meaningful display.

The information obtained through this study supports the authors premise that DVR will enhance retention of engineering material and increase student engagement using the technology already available in universities.

Future Work

The DVR results obtained from this study will be the foundation for future studies. The understanding gained with this study allows other researchers to proceed with the development and understanding of a variety of engineering teaching tools. The authors will continue assessing DVR more extensively. They will use a case study within construction engineering to compare the use of DVR vs. traditional educational approaches. The comparison will focus on knowledge retention among engineering students. The authors will also deploy the DVR internationally as a multilingual teaching tool; a module in Spanish has been already prepared. It is expected that the test will take place in 2001. The DVR described in this paper can be found at: http://epitome.ce.gatech.edu/~tulio.

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