Usability in Virtual Reality Construction Scheduling Education

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Abstract – The usability of Virtual Reality for various training and experiential learning tasks has been the subject of considerable recent research. But, very little direct measurement of the usability of Virtual Reality interfaces has been presented in the literature. This paper presents experimental design and early results of classroom Virtual Reality exercises intended to gauge ISO 9241 requirement compliance for a Virtual Reality Construction sequencing learning experience.

Keywords: Virtual Reality, Usability

INTRODUCTION

Students in Construction Engineering are currently learning to analyze designs, and formulate construction plans, estimate costs and schedule projects using 2D drawings. Aside from 3D drawings in CAD classes, few advanced visualization techniques are used in higher education construction education curricula [1, 2]. Educators tend to rely on 2D drawings, Critical Path Method, and Gantt charts to schedule a project. Because students are unable to visualize or experience the consequences of a scheduling decision, their ability to comprehend the impact of their decisions is limited [3, 4]. In addition, the 2D format may not meet the learning needs of contemporary students [5, 6] Some research suggests that students can understand construction projects much better when advanced visualization tools are used [7]. Time and safety issues make it impractical to visit a real construction site. As a result, the students get very limited hands-on experiences. Because the time-space conflict of activity on a job site can be a major source of productivity loss, it is important to provide hands-on experience that allows students to rehearse the construction project before they work on a real construction site. Research does suggest that students learn best from their own experience [3, 7, 8].

The key to the expected gains from 3D interaction is the usability of the Virtual Reality environment as experienced by the students. Although usability of Virtual Reality has been a subject of considerable academic interest [9, 10, 11], few concrete tests have been done on live subjects to determine actual usability as experienced by motivated users such as students.

In order to test usability the Virtual Reality Schedule Simulator (VRSS) learning environment was introduced to students who then filled out questionnaires related to their experience in the environment. Figure 1 shows two stages of the learning process in VRSS.

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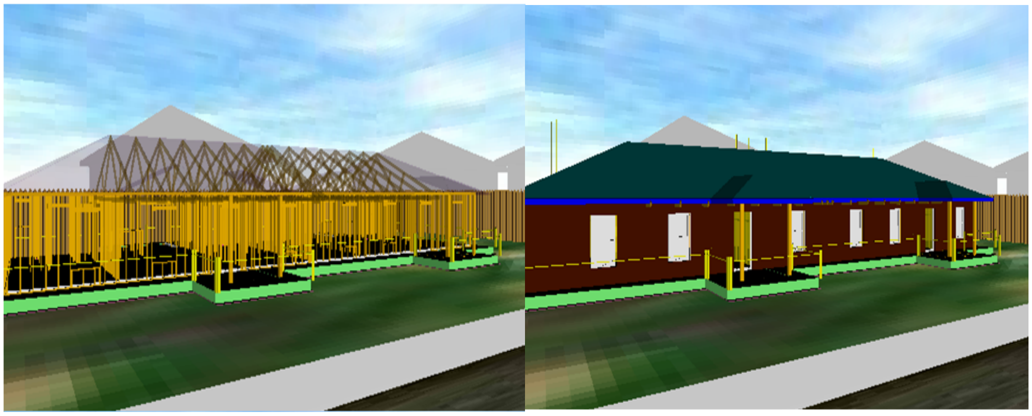

Figure 1: Two stages of the construction of Visualization Generated by the VRSS

The project was funded by the National Science Foundation and developed by The University of Southern Mississippi School of Construction in conjunction with Jones County Junior College Department of Drafting and Design Technology. The VRSS consists of a desktop web based Distributed Virtual Reality (DVR) module where the students can schedule a construction project after studying the corresponding building design drawings. Samples of the web presentation of building design drawings are presented in Figures 2 and 3.

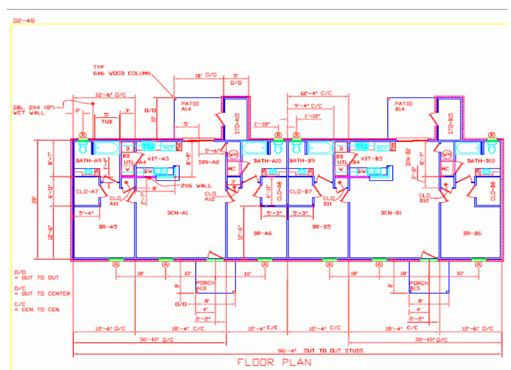

Figure 2: Sample Web-presented Design Drawings of a Construction Project in VRSS

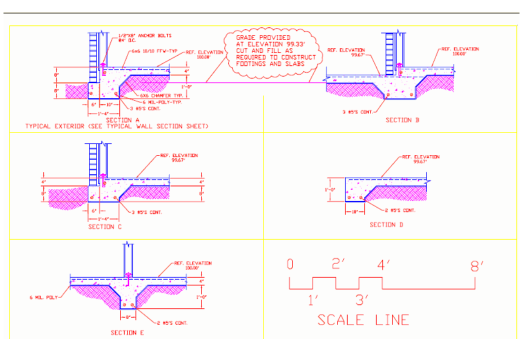

Figure 3: Sample Web-presented Detail Drawings of a Construction Project in VRSS

The students were asked to complete the schedule of the project. Upon completing this step each student presses a button and the VRSS simulates the construction of a building using the student's schedule. If an error in scheduling is made, the VRSS stops at that point and the error is colored in red. Also, VRSS adds additional cost and time to the construction project. This penalty corresponds with the real life cost of construction scheduling errors. Students must then identify the scheduling mistake and re-schedule again until the construction project is complete. The student objective within the VRSS was to complete the construction schedule with the minimum number of mistakes.

The VRSS was designed to provide students with hands-on experience in scheduling a construction project and to experience the consequences both visually and productively in terms of cost and time. The VRSS was developed for use in the classroom. However, it is accessible from anywhere via the Internet by a typical multimedia computer. Therefore, it can be used as an online learning tool as well. Since the tool is new, it needed to be tested for usability, pedagogical merit and student motivation. During the evaluation process, a usability, motivation and learning assessment instrument was administered to the students to quantify the impact of the VRSS. This paper focuses primarily on presentation and analysis of the cognitive development results of the two-year VRSS experiment.

IMPLEMENTATION AND ASSESSMENT

The implementation and assessment were based on an experimental methodology. As indicated by Melville, the experimental research identifies the variables of interest and seeks to determine if changes in one variable (independent variable) results in changes in another (dependent variable) [12]. In this research, the independent variable is the instructional media used to develop higher-order thinking skills (traditional vs. edutainment DVR), and the dependent variable is the cognitive level gained during the learning process (higher-order thinking skills).

During the assessment, pre-testing and post-testing were used to measure cognitive understanding of the topic. The assessment was implemented by dividing the sample group into two groups (Control and Intervention with edutainment DVR). A Pre-test was administered (to both groups). Following the administration of the pre-test, the control group was assigned a scheduling activity using traditional classroom pedagogy while the intervention group was assigned a scheduling activity to be performed in the edutainment DVR prototype. It is important to highlight that the only difference between the control group and the intervention group was the instructional media (traditional vs. edutainment DVR). Upon completing the assignment a post-test was administered. Table 1 shows the matrix of groups, activities, and post-test/survey.

Sample Group	
Control Group	**Intervention Group**
Scheduling Activity with Traditional Classroom Pedagogy	Scheduling Activity Interacting with Edutainment DVR Prototype
Post-Test Survey	

Table 1. Matrix of activities showing for usability testing of VRSS edutainment learning environment.

The test was composed of 25 multiple choice questions as shown Figure 4 as well as open ended questions to solicit comments from the participating students.

Read each statement carefully and then select one of these five alternatives: Strongly Agree (SA), Agree (A), Undecided (U), Disagree (D), Strongly Disagree (SD).

Throughout the learning experience:

	SA	A	U	D	SD
101. appropriate help was easily accessible whenever additional explanation was requested (3-2)	☐	☐	☐	☐	☐
102. the steps required for completion of each task were necessary (3-2)	☐	☐	☐	☐	☐
103. there were times when more information or additional tools were needed but unavailable (3-2)	☐	☐	☐	☐	☐

Figure 4. Sample multiple choice questions from VRSS usability experiment

Data Preparation

Responses and graded pre-test and post-test answers were collected from 4 sets of students over the two year experiment and collated into an EXCEL spreadsheet. This data collection was scanned for basic correctness, for example questions where the student made no response were marked as missing. Each response including the sub-parts of the three scheduling sequence questions were given an equal weight of 1. Therefore, the maximum score was 25 and the minimum score was 0. From this data three sets were developed: the control group which had done paper and pencil exercises, the VRSS group which had done the DVR exercise and the group of the whole which included both VRSS and control students. These data sets were then imported into SPSS for further analysis.

Descriptive Statistics

Basic descriptive statistical analysis of the VRSS dataset was run in SPSS. The VRSS dataset included 45 students in the control group and 41 students in the intervention (VRSS). The totals for the experiment are shown in the Table 2.

Table 2. Distribution of Usability Survey

Group	Frequency	Percentage
Control	45	52.3
VR	41	47.7
Total	86	100

Table 3 below shows moderately higher usability scores for the paper and pencil group vs. the Virtual Reality experimental experience.

Table 3. Descriptive statistics for VRSS experiment

Total Usability Score

Group	N	Mean	Median	Minimum	Maximum	Range	Variance
CONTROL	41	19.0508	19.0000	10.67	25.75	15.08	11.460
VRSS	40	17.3521	17.3333	9.00	25.75	16.75	12.287
Total	81	18.2119	17.6667	9.00	25.75	16.75	12.450

Inferential Statistics

Table 4 shows inferential analysis on the VRSS experiment with the conclusion that the small advantage in the usability of paper-and-pencil exercises was statistically significant.

Table 4: Statistical significance of finding of difference between usability of Virtual Reality exercises and traditional paper and pencil exercises.

Between-Subjects Factors

		N
Group	CONTROL	41
	VRSS	40

Tests of Between-Subjects Effects

Dependent Variable:Total Usability Score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	58.426[a]	1	58.426	4.923	.029
Intercept	26830.620	1	26830.620	2260.680	.000
Group	58.426	1	58.426	4.923	.029
Error	937.602	79	11.868		
Total	27861.667	81			
Corrected Total	996.028	80			

a. R Squared = .059 (Adjusted R Squared = .047)

However, the difference found between the usability of Virtual Reality exercises and paper and pencil exercises was small, less than a standard deviation apart.

CONCLUSION

The conclusion from the VRSS experiment is that more work needs to be done to increase the usability of Virtual Reality for learning exercises to be as easy to use as traditional methods. One of the USM research groups current focuses is the use of more complex and interesting models in the Virtual Environment as shown in Figure 4.

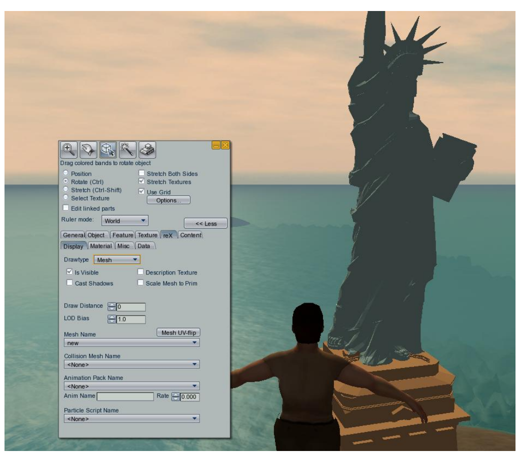

Figure 4: New modeling technology in Virtual Reality which may overcome usability issues.

The expectation is that new technology and development will overcome the usability barrier identified in the VRSS study

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