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Efficacy of Virtual Models in a Production Systems Course

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Abstract

Wichita State University has developed an integrated set of virtual reality models of an aircraft assembly line. These models are intended to provide students an 'artifact' of industrial and manufacturing engineering by providing a realistic environment for initial learning and application. By utilizing a virtual model of the line, students are able to view the process and interrogate the process details, make changes and observe the effects, and gain a better understanding of the concepts and their interrelationships. This paper presents the method used to assess if virtual models (computer models of a real factory) lead to: improved perception of relevance, increased time on task, and increased student satisfaction. A production systems class was used to determine student impacts. This paper presents preliminary results.

Motivation

Students learn better when engaged. Students learn better when they are involved in the process and can apply their learning[1][2]. Gorman, et al. [3] propose that cases aid engineering students ability to apply classroom concepts to engineering practice. The more open-ended the application, the better suited the case study. Frequently, students can learn the concepts to pass a test or complete the homework assignment, but the students have not obtained the practical knowledge to perform the task. Therefore, case studies are developed to aid in preparing students to perform engineering tasks.

Case studies, in general, are considered helpful. But, this research asks the question, do virtual case studies have an additional impact?

Background and history of course

Virtual reality has been around for decades. The definition of virtual reality greatly varies according to the author. Virtual reality (VR) is beginning to be widely used in fields such as entertainment, medicine, military training, and industrial design. Virtual reality models of manufacturing systems range in complexity from the level of a single process on a single machine [4], to flexible manufacturing cells [5], to models of entire factories[6]. VR models are typically distributed over the web using the Virtual Reality Modeling Language (VRML) format. As Ross and Aukstakalnis indicate [7], virtual reality is used in the engineering design process, so we should be incorporating virtual reality in engineering education.

Jones et al. [8] discuss the use of virtual reality to present the results of simulations as a “super” graphical animation that will lead to an expanded role of simulation in decision-making and communication. Lefort and Kesavadas [9] have developed a fully immersive virtual factory testbed for designers to test issues such as plant layout, clusters, and part flow analysis. Many researchers [10][11][12] have discussed the use of large-scale simulations for studying the virtual behavior of factories. Virtual factories have also been used for simulation-based control of real factories [13], and for studying the interaction between business decisions and quality [14]. Impelluso and Metoyer-Guidry [15]use VR in engineering education to facilitate constructivist learning and enable experimentation with design.

The production systems course at WSU was modified in 1999 to incorporate variability in much of the content. A half semester long case-study based active learning project was added in 2001 to stimulate student interest and understanding of factory systems [16]. As part of an overall effort to incorporate virtual reality with a single case study, the initial version of this module was implemented in the production systems course [17].

Method

A primary aspect of this study was the concept of student motivation. Arnone [18] considers the concept of curiosity and presents several instructional design strategies for fostering curiosity. The first strategy presented is to use ‘curiosity as a hook.’ The method in our study is to use curiosity in the Virtual factory to get students interested in the task at hand. Flowerday and Schraw [19] reinforce this by finding that even short-term motivation can have a positive impact into the amount of time spent studying. A detailed study by Azevedo, et al. [20], showed that the amount and flexibility of the scaffolding provided impact student learning when using multimedia. Hong, et al. [21] found that the discipline studies impacts student self-efficacy towards computers.

Participants from the Fall 2005 Production Systems classes (60% graduate/40% undergraduate) were randomly assigned to either an experimental or control group for one homework assignment regarding Economic Order Quantity (EOQ). The assignment required students to calculate this quantity for three different parts. The traditional EOQ equation does not apply for one of the parts. The experimental group used a virtual computer model case study and the control group used only a written case study. It was hypothesized that the students in the virtual case study group would perceive more relevance of the assignment, would spend more time on the task, and report higher levels of satisfaction. Both groups of students completed the same homework assignment and received the same instruction. Those who did not view the virtual model for the assignment were given an opportunity after the assignment has been completed. Two surveys were completed by all participants. The first survey administered after the students completed the assignment and the second was administered after a class discussion of the assignment. In both surveys, students were asked to indicate how effective the homework assignment was and how helpful it was to solving a real-world engineering problem. The reason for administering the survey after the homework and after the class discussion was because it was expected that the class discussion of the homework would enhance (solidify) the students' understanding of the material and result in stronger opinions of its effectiveness. In addition to this survey, students also indicated the amount of total time they spent on the assignment.

Virtual reality module

The virtual reality module developed for this effort is about a worker performing a setup and assembling a part.

The text for the assignment follows:

> *You are the production manager for the Boeing 767 GE strut line. You need to create a Bill of Materials (BOM) based on the information you know about the 767 GE strut and determine the Economic Order Quantity (EOQ) for the mid spar, lot time part #123, and Type I rivets. The cost of the mid spar is $100,000, the cost of the lot time part is $100, and the cost of one Type I rivet is $0.03. Assume the holding cost is 10% of the cost of the item. Boeing must manufacture 60 struts per year. Assume that 400 Type I rivets are required to assemble the midspar into a strut. Also, assume that 100 Type I rivets and two lot time parts (#123) are required to assemble the mid spar. Assume that the ordering cost for the rivets is $10 and the setup time for the mid spar is 100 hours. To calculate the setup cost for the lot time part, you will first need to determine the setup time by viewing the Lot Time Part #123 Process model and recording the tasks and task durations for this process. Then you will need to determine which tasks you consider to be setup. Assume that it costs $20.00 for each hour of setup for both the lot time part and the mid spar.*

Preliminary results

Mean scores for each survey item by group is shown in Tables 1 and 2. Results from a series of independent sample t-tests indicate that while there was a tendency for the experimental group that received the virtual model in the homework to be more positive about the effectiveness of the assignment, none of the scores were significantly different at the $p = .05$ level. Final scores were marginally in favor of the virtual model group ($p = .07$). It should be noted that the sample size used in this study was small. Further study using a larger pool of participants would determine whether this trend for increased perceived relevance and satisfaction holds true.

Table 1. Mean scores (SD) post-homework by group

(1 = not effective; 5 = very effective)	Written Instructions Only	Virtual Model & Written Instructions
Effective for developing skills to handle engineering tasks	2.87 (.64)	3.83 (1.16)
Effective for linking theory to	3.5 (1.07)	4.3 (.82)

real world		
Effective for improving problem-solving skills	4.0 (.53)	4.0 (.63)
Effective in developing appreciation for EOQ	4.0 (.92)	3.6 (.52)
(0 = No; 10 = Yes)		
Ability to solve problems without doing homework	5.87(2.47)	5.0 (2.52)
Ability to solve problems after doing homework	8.5 (1.19)	8.5 (1.22)
Total time (minutes) spent on homework	103.57 (70.28)	158.00 (21.68)
Final score on homework (out of 20)	17.37 (1.51)	18.67 (.52)

Table 2. Mean scores (SD) post-homework and post-discussion by group

(1 = not effective; 5 = very effective)	Written Instructions Only	Virtual Model & Written Instructions
Effective for developing skills to handle engineering tasks	3.50 (.84)	4.33 (.52)
Effective for linking theory to real world	4.0 (1.09)	4.33 (.82)
Effective for improving problem-solving skills	4.0 (.63)	3.83 (.41)
Effective in developing appreciation for EOQ	4.33 (.82)	4.0 (.63)
(0 = No; 10 = Yes)		
Ability to solve problems without doing homework	5.17 (1.17)	5.33 (2.65)
Ability to solve problems after doing homework	8.33 (1.21)	8.5 (1.22)

Summary and Future Directions

The survey showed that student perception of relevance is much increased when using any case study. Time on task and effort on the problem are very subjective measures unless monitored very closely. However, this monitoring may also cause bias in the data (Hawthorne Effect). Therefore, to properly determine if virtual reality is leading to improved perception of relevance, increased time on task, and increased student satisfaction, the survey and method must be modified.

The Fall 2006 production systems class will perform the tasks again, but with a varied method to improve the usefulness of the results. There will still be two randomly selected groups. Group 1 will receive a word problem (the text will be smoothly integrated into the problem, whereas in the previous effort the text was separated for clarity. Group 2 will get the same VR model as previous but without the pop up window with the text. Both groups will be told to breakup the activity into tasks and determine if setup or not. The same survey as before will be administered. However, for the second stage both groups will receive a different and newly developed VR model without a popup window. This additional problem will be assigned later in the semester. A final modified survey will be administered.

Virtual reality holds the potential to encourage students to spend more time on task by capturing and maintaining their interest. To show that student efficacy is increased with these types of efforts, additional research is required.

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