IMPLEMENTING DESIGN-BASED ENGINEERING EDUCATION WITH COMPUTER SIMULATIONS

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ABSTRACT

Design-Based Engineering Education (DBEE) is a method for introducing design into basic engineering science courses. DBEE uses specially structured computer-simulation modules to introduce basic principles through a discovery-learning process. The DBEE modules are supported by Working Model™; an engineering simulation software package developed and marketed by Knowledge Revolution. The DBEE modules are open-ended situations incorporating two important target concepts. The modules are structured to ensure that target concepts are discovered by the student during successful completion of the module. The modules typically require an hour to complete, and are assigned in place of two traditional drill problems. DBEE uses design to introduce basic concepts; therefore, the inclusion of DBEE into engineering science courses does not require additional study time from the student. The DBEE project was implemented in a 1995 pilot study partially funded by an equipment grant from Hewlett-Packard. Following the success of the pilot project, a grant was obtained from the Idaho State Board of Education to implement DBEE in Statics and Dynamics courses at the three engineering colleges in Idaho. The implementation and evaluation of DBEE in an Internet-based environment will be presented and discussed, and results will be critically assessed. The evaluation process used in our study can easily be adapted to measure the effectiveness of other innovative teaching methods.

INTRODUCTION

Rapid advances in computer technology and software development continually increase the effectiveness and availability of very powerful simulation software. However, there are few, if any, practical guidelines for effectively integrating simulation software into engineering curricula. The authors recently received funding from the Idaho State Board of Education to enhance two basic engineering science courses at the three colleges of engineering in Idaho. The centerpiece of the Internet-based project is Working Model™. Working Model™ is a widely used engineering mechanics simulation program marketed by Knowledge Revolution[1].

The primary goal of the project is to enhance statics and dynamics courses by incorporating design-based modules into the curriculum; therefore, we call the project Design-Based Engineering Education (DBEE). The DBEE modules are structured to provide student ownership through open-ended design problems, while reinforcing important concepts in statics and dynamics. To ensure effective implementation and evaluation of the DBEE project we collaborated with the Department of Instructional and Performance Technology (I&PT), a graduate program at Boise State University. Faculty in the I&PT department specialize in instructional design, distance education, and evaluation. The objective of the collaborative effort between faculty in engineering and faculty in I&PT is to develop a structured environment for the effective delivery, assessment, and continued improvement of Design-Based Engineering Education.

This paper summarizes the results available at the midpoint of the DBEE project, which began in the Fall semester of 1997.

BACKGROUND

Drill problems are typical of the homework assigned in engineering courses such as statics and dynamics. Drill problems provide opportunities for students to develop and practice their skills in analysis and problem solving; however, drill problems often bear little resemblance to real world situations. Carrol[2] emphasized that drill problems are short, well defined, and have one correct answer, while real world problems are longer, less clearly defined, and have many solutions.

Many methods have been developed to integrate design into the freshman and sophomore years of engineering curriculum. Efforts by Van Valkenburg[3] and Sadowski[4] to incorporate design involve major curriculum changes. Another widely accepted solution is addition of a freshman design project. Perhaps the easiest approach, as suggested by Koen[5], is to make small changes in the content of existing courses; this is the approach taken by the authors.

First-hand experience with the reluctance of new engineers to participate in design projects led the authors to develop a method for introducing simple open-ended design modules into the basic engineering courses of Statics and Dynamics. The objectives for the modules are to provide a positive design experience, and reinforce important concepts in engineering mechanics. The authors developed modules using Working Model™, a PC-based engineering mechanics simulator program. Each module takes from two to four hours to develop. Students using the modules easily change design parameters, such as spring constants or support angles, and immediately observe the results of their changes. The authors used three rules to develop the modules:

(1) Each situation must have an infinite number of solutions;
(2) The number of target concepts to be reinforced is equal to the number of changeable design elements; and
(3) The results must be verifiable by the student.

A screen sample from one of the DBEE modules is shown in figure 1.

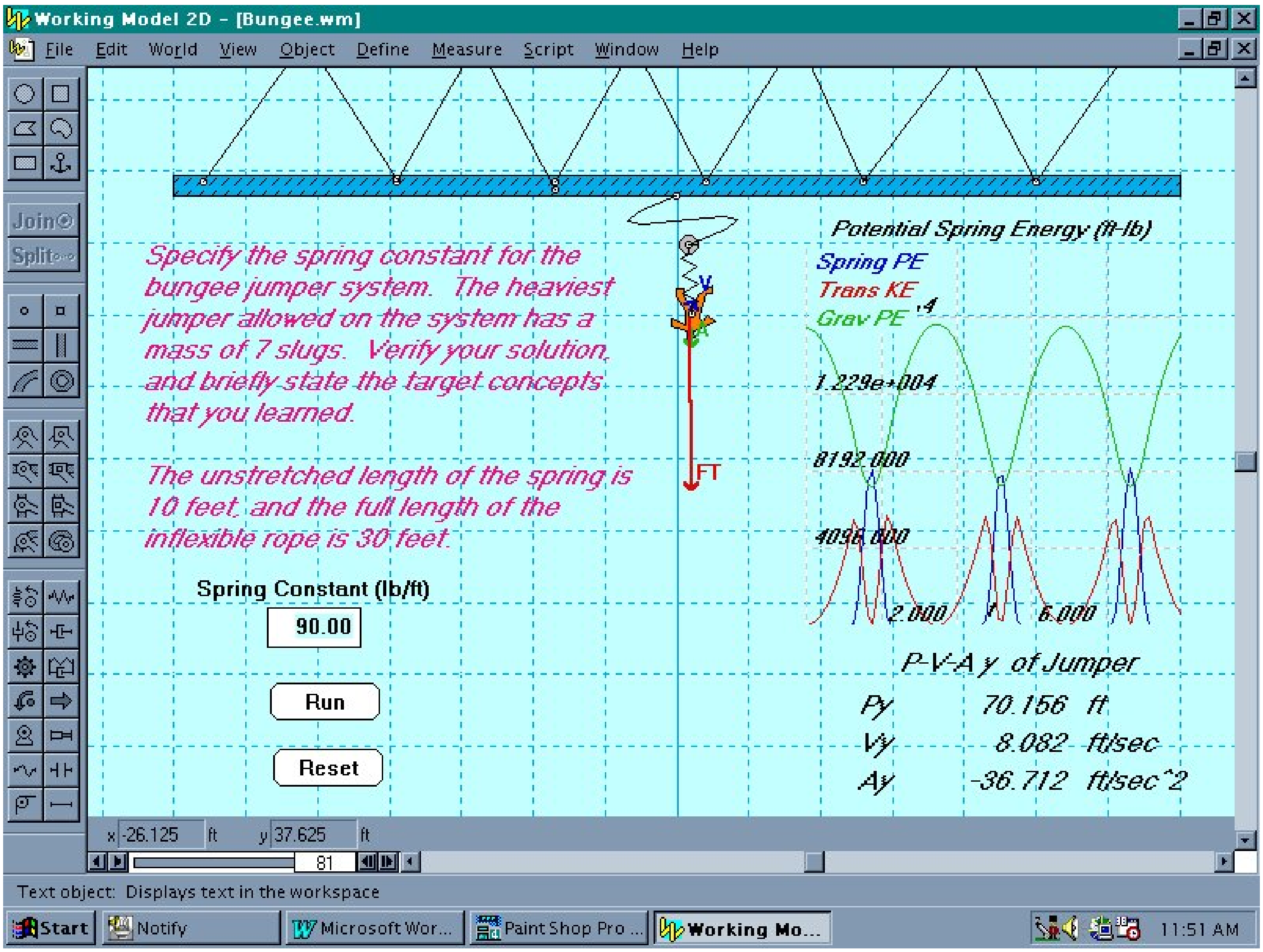

Figure 1
Working Model™ Screen from a DBEE Module

The funding obtained from the Idaho State Board of Education's Technology Incentives Grant Program (TIGP) was used to develop the modules, structure the delivery method, and implement the DBEE project in the Fall semester of 1997. Collaborating faculty from the University of Idaho and Idaho State University served as co-requesters on the TIGP grant, and provided valuable suggestions and enthusiastic support for the DBEE project.

There are fundamental differences in the three participating Universities. The University of Idaho, in Moscow, Idaho, has more "traditional" students than the other two Universities, with active fraternities and sororities, and a very large student population living on campus. Boise State University, in Boise, Idaho, is located in the largest urban area in Idaho, and most students live off campus. The student population at Idaho State University, in Pocatello, Idaho, consists of traditional and non-traditional students with a more equal distribution than the other schools.

Numerous planning sessions, culminating in a two-day organizational workshop at Boise State University, preceded the Fall 1997 semester. A representative from Knowledge Revolution attended the workshop and provided valuable input on using Working Model™ for DBEE. Faculty from the three universities agreed on an implementation plan structured by the project director and I&PT. The project director administered the grant and developed an evaluation consistent with the implementation plan.

METHOD

The three crucial elements of the DBEE project are delivery, evaluation, and continued improvement.

Delivery

Topics for DBEE modules were requested from the engineering professors collaborating in the project. The authors and a senior mechanical engineering student at BSU, developed and tested DBEE modules based upon the list of topics provided by the participants. The modules are multi-media representations of a "real-world" situation. Each module contains; a problem statement, animation, data input fields, and an immediate feedback mechanism.

The DBEE modules were designed to replace one or two conventional drill problems. Each participating professor was asked to assign at least ten DBEE modules throughout the semester. Each DBEE module was envisioned to require an hour or less to complete.

The DBEE modules are hosted on a web site (URL: http//coe.idbsu.edu/dbee). The modules are arranged by subject with descriptive hypertext links. Students access the web site from computer labs hosting Working Model™ software at each university. Students click on the hypertext associated with the assigned module, and the appropriate Working Model™ file downloads to the computer. The student reads the problem statement, designs a solution, inputs information into the data fields and clicks the "run" button to begin the simulation. The animation provides immediate feedback to the students regarding their designed solution. Students then have an opportunity to alter their designs until their solution satisfied the conditions of the problem statement.

A DBEE assignment form was developed during the workshop to ensure uniformity and streamline the evaluation process. Students were asked to follow the format outlined in the DBEE assignment form when turning in their DBEE projects. The DBEE assignment form requires the students to identify the concepts that are reinforced, provide rationale for their design decisions, and mathematically verify their results.

The DBEE web site hosts a discussion page in addition to the DBEE modules. Students are encouraged to post comments and insights on the discussion page throughout the semester.

The grant director, and a researcher in the I&PT department, conducted site visits at the University of Idaho and Idaho State University before the Fall 1997 semester. The site visits addressed last-minute concerns of participating faculty, and verified that adequate resources were in place for implementing the DBEE project.

Evaluation

A unique evaluation plan was developed and implemented. The evaluation was designed to measure changes in student's attitudes towards engineering courses, and the student's grasp of basic concepts in Statics and Dynamics. We used a pre-test, post-test, matched pair experimental design, paired with qualitative analysis of assignment forms, and instructor feedback surveys. Students responded to a brief multiple-choice skills test and a College Course Expectation questionnaire at the beginning of the semester. The questionnaire was based upon a five-point Likert scale ranging from strongly disagree (1) to strongly agree (5). At the end of the semester students responded to the same skills test and a College Course Attitude Assessment. The expectation questionnaire and the attitude assessment were identical except for slight rewording of the items on the latter to represent the student's feelings after completing the course. The first semester of the DBEE project was formatively evaluated by the net change in student skills, the level of satisfaction with the course, and the module assignment forms.

Continued Improvement

The results facilitated discussion of critical issues and modification of the project for ensuing semesters. Comments made by faculty and students were discussed by participating faculty after the Fall 1997 semester. Project changes were made based on results of the evaluation.

RESULTS

The evaluation results from the Fall, 1997 semester show that the skill level in both statics and dynamics improved significantly. Further, data from the skills tests showed that average scores for students in all courses except one had equal improvement (one course had significantly greater improvement than the others). The lack of a control group prevented a meaningful benchmark for absolute comparison.

Preliminary results from the expectation/satisfaction questionnaires indicated that most of the student's expectations were met in statics. Preliminary results for dynamics indicated that student expectations were not met. Further analysis is being done to determine if there are any differences due to demographics.

Results from the qualitative analysis of the assignment forms indicate that the students were able to accurately identify the target concepts. Further, students' rationale for design decisions included important design elements such as safety, aesthetics, and cost. However, some students had difficulty with the mathematical verification; this difficulty was largely due to student attempts to go beyond what was expected to provide mathematical verification.

Opportunities for Improvement

The formative evaluation of the project revealed several opportunities for improvement:

- Three out of four classes at the participating remote universities did not implement the DBEE modules for the first three weeks of the semester. The principle reasons for the delay in implementation were technical problems and unfamiliarity with the software.
- Most students in dynamics at the University of Idaho used the discussion page extensively. The other students rarely used the discussion page, even after repeated suggestions by faculty. Almost all the comments made on the discussion page were very informative.
- The faculty had problems interpreting the nature and scope of the mathematical verification required in the DBEE assignments, due primarily to the authors' inability to communicate the requirements.
- The faculty teaching Statics were concerned about the limited range of topics represented by the modules.
- Three of the DBEE modules in Statics were found to have serious problems, which were pointed out by the professors who assigned the modules. One problem was due to subtle differences between versions of the software, while the other two problems were not detected in the testing phase of the DBEE project.
- The evaluation design required student's responses to the pre-test instruments be matched to their responses to the post-test instruments. We requested that each student generate a confidential four-digit number at the beginning of the semester. The four-digit number was to be retained by the student and used again on each assessment instrument. Students were asked to write their confidential numbers in their textbooks for reference on the post-tests. Many students wrote down their names on the post-tests, rather than their confidential numbers, which required the elimination of valuable data from our study, and voided the entire control group.

Improvements for Spring, 1998

Technical problems, which caused a delay in implementation of the DBEE project at the remote Universities, have been resolved.

The dynamics professor at the University of Idaho required students to post their target concepts and design rationales on the discussion page. The value of the posts was so high that several of the faculty are considering the adoption of the policy followed by the dynamics professor at the University of Idaho.

The mathematical verification requirement has been modified. The assignments now require a brief discussion of the solution. Requiring a discussion of the solution, rather than a rigorous mathematical verification, will hopefully have the added benefit of reducing the time required for each assignment.

More modules are being developed for Statics to represent a wider scope of applications. Current modules are being modified to be more realistic, and technical problems with the modules have been resolved.

We lost valuable data due to our unsatisfactory resolution of the confidentiality problems posed by the pre and post-test format. We are exploring new ways to maintain confidentiality while minimizing the loss of data from students.

Conclusions:

Comments from students and faculty regarding the modules have mostly been positive. Most of the students enjoy solving open-ended design problems. The modules encourage students to think about design principles and provide rationale for design decisions. We have no data from the control group; therefore, we are unable to conclude that DBEE will increase students understanding of statics and dynamics. However, DBEE students were able to correctly identify the target concepts. In addition, they considered important design elements in their solutions. Implementation of DBEE in statics and dynamics did not have a negative effect on learning outcomes for the fall semester.

Results of the first semester are promising. We have implemented the changes revealed by the formative evaluation and are proceeding with the second semester.

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