Teaching Design Engineering Technology:
Experiential Learning Activities

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Abstract
This research shows that experiential learning using problem-based simulation activities was perceived by students and teachers as a valuable tool to use in design engineering and in the education of CAD/Drafting students. The simulation activities offer many advantages to the user in visualizing results and being able to predict more accurately answers to problems. Results are shared from action research projects involving high school design/CAD students, university workshop participants, and university mechanical engineering technology students.

Introduction
In recent years many engineering design software products have incorporated dynamic analysis capabilities into their 3D solid modeling packages with the capability to solve motion related problems. In the study, "Engaging Teachers and Students in Problem-based Simulation Activities", it is stated that simulation of the dynamics of mechanisms used in engineering technology curricula is a new concept rarely studied (Irwin, 2006). In the past two years the use of computer simulation has increased, software has become more advanced and research of simulated learning activities has increased. Even though research in this area is growing, there still remains a lack of understanding of how simulations can be used most effectively in engineering education.

The following is a review of the quantitative results from this 2006 quasi-experimental action research study, which investigates the perceptions of teachers and students involved in problem-based simulation activities used in high school design engineering curricula. The purpose of the research is to investigate the potential for problem-based simulation activities to be used as curriculum and instruction aids for engineering educators. Also included is a discussion of survey results from engineering faculty who attended NSF sponsored workshops designed to learn and practice problem-based simulation activities using dynamic analysis software, and reactions from university students experiencing the experiential learning activities first hand.

The research problem statement in this 2006 study is to investigate the perceptions of teachers and students involved in problem-based simulation activities used in high school design engineering curriculum to introduce simulation as a design tool to better evaluate design solutions. This paper will focus on the first objectives of this study, which is to document the achievement level of one group of technology high school students using the problem-based simulation activities compared to another group using traditional methods of instruction.

Simulation, Problem-Based Learning in Education

For the brevity of this paper, it is suffice to state that there is extensive literary research in the area of simulation and problem-based learning, and only a selected few will be highlighted. First, research tells us those learning activities which recreate work situations foster better transfer of learning (Swanson and Holton, 1999). Through the process of experimentation, application of theoretical concepts to the simulated environment and feedback providing important insights impossible through other learning methods, simulations have been proven to enhance the learner's ability to make quick progress in skill development. Second, in problem-based approaches, students clearly define the problem, develop hypotheses, gather information, and arrive at a clearly stated solution, (Allen, 1998). Combining a problem-based approach and using simulation software as a tool for verification and hypothesis checking is the theoretical basis of this curriculum being studied.

Content and Context of the Study

This research is related to the products developed through a NSF grant to integrate simulation into Design Engineering Technology (DET) associate degree programs. NSF funded the development of Tech Prep/associate degree activities that focus on 3D CAD model simulations developed in the State of Michigan by Mott Community College (MCC), in cooperation with Henry Ford, Macomb and Oakland Community Colleges and their K-12 partners. The three modules developed for threads, gears and cams were chosen for this study because they were the first three developed and they are most applicable to high school students. The design of the threads, cams and gears simulation activities allow the learners to engage in the activity and to progress to the next step at their own pace. If the learners solve a problem incorrectly they can run the simulation results over and over until they understand the concept. The simulation activities were developed using the Autodesk Inventor software for the 3D models and the Design Simulation Technologies software Dynamic Designer product for the motion analysis.

The design involves assignment of two groups of subjects from the accessible population; the treatment group will get the intervention activities, (the simulation activities) and the comparison group will get the usual activities, (the standard curriculum). The subjects shown in Table 1 are students at three high schools in Genesee County, Michigan. All three of the high school classes chosen for this study have similar course descriptions and require similar experience and prerequisite skills. Although, shown in Figure 1 the students from School C, who make up about 70% of the comparison group, have had no previous drafting background, in contrast to the treatment group where about 66% have had one or two years of experience.

	School A	School B		School C			Totals	
	Treatment Group	Treatment Group	Compare Group	Treatment Group	Compare Group	Compare Group	Treatment Group	Compare Group
Total number of Students	23	20	20	21	21	24	64	65
Female Students	2	2	2	3	2	3	7	7
Male Students	21	18	18	18	19	21	57	58
Students Grade Level - 9	1	0	0	11	11	13	12	24
Students Grade Level - 10	3	10	8	5	7	7	18	22
Students Grade Level - 11	9	7	11	2	2	1	18	14
Students Grade Level - 12	10	3	1	3	1	3	16	5
First year in Drafting	0	0	0	21	21	24	21	45
Second year in Drafting	18	20	20	0	0	0	38	20
Third year in Drafting	5	0	0	0	0	0	5	0

Table 1 - Student Comparison and Treatment Group Demographics

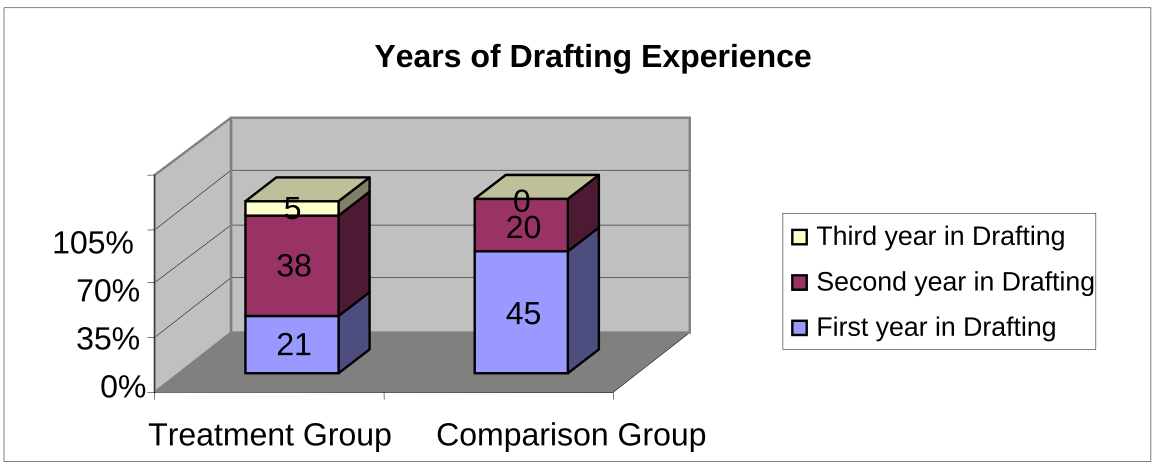

Figure 1 – Research Sample Experience Comparison

Research Design Methodology

The design structure for the quantitative research is quasi-experimental because of the lack of true randomization. Observations will be conducted at the conclusion of each unit of intervention using a standard post-test instrument. The post-test only design is used because the subject matter being taught is new information that students in the study have not been exposed to in the past so they need not be tested on their prior knowledge of the material.

Data Collection and Analysis Methodology

The post-test scores for each unit taught were recorded for each student in the comparison and treatment group and entered anonymously into a table of scores for that group. The post-test consists of multiple choice written questions, and short answer. Performance CAD modeling assessments were not used in this study, because the performance involves a very time intensive CAD project for which the high school students were not sufficiently prepared.

The null hypothesis is that there is no difference in the two groups in terms of the students' performance on the post-test. A non-parametric test is conducted, because there is no reason to believe that the scores will be normally distributed. The analysis of the post-test scores is performed using the Wilcoxon Rank-Sum Test, because of the hypothesis of differences in average performance.

Results

The study was conducted over a two-month period from March through April of 2005. Each school had a different approach to the integration of the activities into their regular schedule of high school functions including MEAP testing and spring break. Figure 2 represents the amount of time allotted to teaching the topics of cams, gears and threads for the comparison and treatment groups of students at the individual schools.

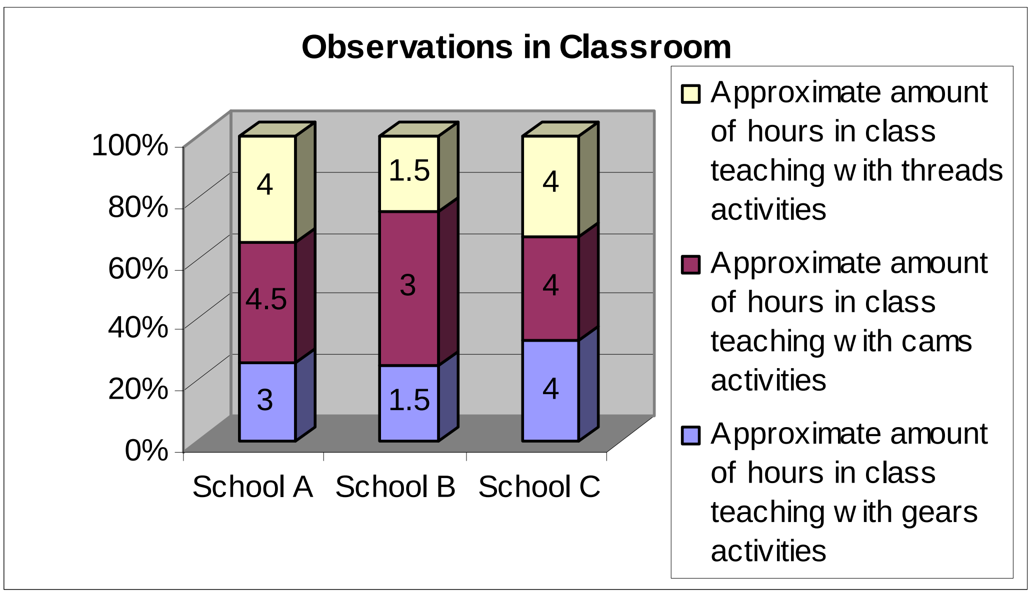

Figure 2 – Classroom time using PBL Simulation Activities

Quantitative results

After the students in the treatment groups were given the intervention (the simulation activities for the units of cams, gears and threads) they were tested for their knowledge along with the control group, which had been taught the same topics without the simulation activities. The traditional methods differed in comparison between Schools A, B and C, but generally included doing the thread, gear and cam calculations using written problems and 2D drawing diagrams. Some of the students created 2D drawings of gears, cams, and threads and also did activities involving looking at real gears, cams, and threads on machines and mechanisms.

Ideally both the treatment and comparison groups would have the same traditional activities and the simulations would be a supplement, but because of time restrictions all of the schools used the simulation activities as a substitute and the treatment group did not have time to do any drawing projects of gears, cams and threads before the post tests. Table 2 represents the post test results as group average scores, and also communicates the Wilcoxon statistics, standard deviation of the comparison group and the effect size while Figure 3 illustrates the post test score comparisons as percentages.

Schools A, B and C	Threads	Cams	Gears
Possible points	6	15	17
Treatment group average	3.8667	10.6774	11.7167
Comparison group average	2.3846	8.3934	9.3016
Wilcoxon Rank Sum Z	2.25	4.03	2.97
Standard deviation comparison group	2.17	3.06	4.59
Effect Size	.68	.75	.53

Table 2 – Post Test results

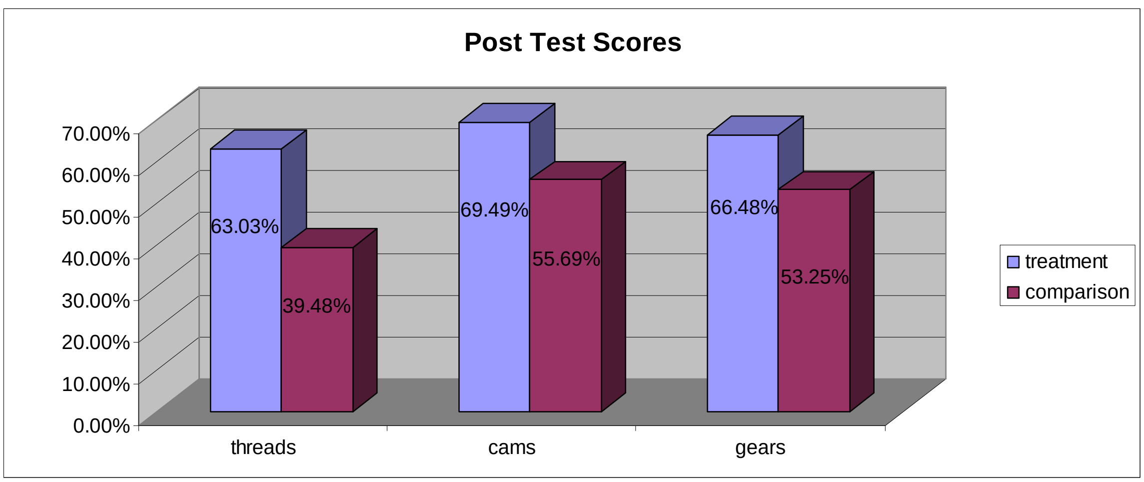

Figure 3 – Post Test Percentages

Conclusions

According to the analysis results of the post-test scores the null hypothesis that there is no significant difference between the comparison and treatment group are false. Influencing the results are the number of students in the control group from School C who had little or no experience with drafting prior to the school year as compared to the larger number of students from Schools A and B with one year of experience in the treatment group. Limitations of the study include the primary researcher's involvement with the delivery of simulation activities and the differences that exist between the control and treatment groups that may have positively influenced the post test results of the treatment group. From the isolated sample in this research it can be concluded that the treatment group of students performed significantly better than the comparison group, and that simulation was perceived by students and teachers as a valuable tool to use in design and in the education of CAD/Drafting students.

After communicating the results of the study with the participant teachers and reflecting upon the experience, some recommendations for further utilization and research of this curriculum are as follows. The time constraints and requirement to have a control group of students not using the simulations in this study forced the teachers to use the simulation activities as a substitute for traditional activities rather than as a supplement to instruction. In order for the teachers to keep the two or three sections of students relatively on pace with each other they did not have the treatment groups do any traditional activities like drawings, or manipulation of physical parts; otherwise, they would have taken a considerably longer time to complete each topic.

Recommendations

As a follow-up to the study the problem-based simulation activities were updated by correcting mistakes in the instructions and better packaging the materials using a CD ROM with interactive PowerPoint media to replace the paper handouts. This was in response to the student and teacher reactions to what they thought did not work well in the curricula. Further study is necessary to indicate if the changes and updates on the curriculum materials would impact the student outcomes. Also, it is recommended that a delivery style including integration of traditional techniques and simulation activities be conducted to study the effect of the simulation activities as a supplement.

Implications

The strengths of the problem-based simulation activities are their ability to grasp the interest of teachers and students because of the highly interactive element of the software. The teacher can modify the simulation models developed to accommodate specific needs of the learner. Once proficient with the simulation software, engineering educators can continue to add to the existing projects or create new applications designed around their course objectives.

2006 NSF Sponsored Workshops

NSF sponsored three-day workshops, two located at MCC and one at the partner location, Sinclair Community College, enrolling over 50 college and university engineering educators interested in learning more about operating the simulation software and utilizing the simulation activities. Participants were also provided a stipend and a one-year subscription for the simulation software to outfit a 25 station lab. Approximately 94% of the “NSF 2006 Design Education with Simulation” teacher workshop participants responded positively that the training met their objectives to be able to integrate simulation concepts into their curriculum at their institutions. The survey of instructor reactions to the workshops included several comments praising the quality of projects that can be utilized immediately in their classrooms. It has been difficult to track the usage of the software in the institutions involved in the training, and very little feedback has been provided to the extent of the simulation activities or software usage.

Michigan Technological University Courses

At Tech the simulation activities for gears were used as a learning activity for the 2006 fall semester Product Design and Development senior level course. The purpose of using the activity was to introduce the students to the simulation capabilities of motion software available to analyze mechanisms and to review simple gear calculations for ratios and speed calculations to assist in design projects. Students revisited the simulations to support or reject their assumptions about the gear problems, and took advantage of the interactive capabilities of the activity. Later in the 2006 spring semester several groups explored using the dynamic analysis for their Senior Project course presentations. Also, during the 2006 spring semester Practical Applications in Parametric Modeling course an activity was added to utilize the "Motion Scenario" capabilities in the Unigraphics software. Students simulated a Gear Train, Four Bar Linkage, and a Geneva Mechanism utilizing the capabilities of coupling, 3D contacts, motion drivers, and creating joints. The end of course survey indicated that students viewed the use of simulation analysis as a critical skill necessary for this course, and expressed that an increased emphasis on creating simulations was necessary to fully comprehend the software capabilities.

The Future in Experiential Learning

With laboratory and facility costs continually rising, true hands-on experiences are becoming more difficult to deliver in engineering laboratory settings. So, creating a simulated experience for students is "the next best thing to being there". The problem-based simulation activities still have their limitations because of the difficulty in implementing the activities in a self-paced classroom situation and the time required for students and teachers to master the complex software. Given adequate preparation, problem-based simulation activities offer an advantage for technology educators that are in need of a tool that offers students the opportunity to test out solutions to problems in a simulated environment. The engineering design simulation activities in this study offer many advantages to the user in visualizing results and being able to predict more accurately answers to problems.

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Bibliographical Information

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