AC 2007-2192: THE EFFICACY OF AN ENGINEERING GRAPHICS COURSE FOR BOTH STUDENTS WITH AND WITHOUT PRIOR ENGINEERING GRAPHICS EXPERIENCE

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The efficacy of an engineering graphics course for both students with and without prior engineering graphics experience

Abstract

Students start university-level engineering graphics with varied levels of knowledge. Some students have taken computer aided drafting courses while in high school, while others have no engineering graphics experience at all. This paper considers one college-level engineering graphics course and its effectiveness in educating students with varying levels of knowledge in engineering graphics. This study was performed on two course sections; one section was taught in a traditional face-to-face setting and the other section was delivered though distance education. One objective of the research is to determine the students' proficiency in engineering graphics upon entering and completing the course. This was done through the use of a pretest and posttest. No statistical difference was found between the pretest of the experienced students and the inexperienced students. Also, students improved between the pretest and posttest regardless of their prior engineering graphics experiences. Therefore, students start the college-level course with similar skills and benefit from the course regardless of their engineering graphics experience. However, the course seemed to have little effect on the visualization skills of students as little improvement was made from the pretest to the posttest. The experienced students improved the most on section and auxiliary views, thus students seem to gain from a review of section and auxiliary views. Based on a survey given at the end of the semester, nearly all the students felt they learned something new from the course. Most students with experience in engineering graphics had never used 3D solid modeling CAD software. Also, the majority of students, both experienced and inexperienced, felt the pace and workload in the course were adequate. The few students that felt overwhelmed by the workload and pace of the course understood it was necessary to learn all the required material. Students with familiarity in both AutoCAD and Inventor, the software used in the course, struggled in creating working drawings using AutoCAD. Specifically, they had trouble manually creating the multiview projections and properly dimensioning the drawings. This research finds that all students, regardless of their experience, benefit from taking engineering graphics at the university level.

Introduction

Students start engineering programs with many different experiences. Some students begin an engineering program with some knowledge of engineering graphics. This knowledge of engineering graphics ranges from knowing the basics of technical sketching, to the ability to read technical drawings, to an intimate knowledge of 3D modeling using CAD. Students gain these experiences from many places including job training and high school CAD classes. Most university engineering programs require a course in engineering graphics and students generally take the same course regardless of their abilities. This paper considers one college-level engineering graphics course and its effectiveness in educating students with varying levels of engineering graphics knowledge.

Much research has been devoted to determining the visualization skills of engineering graphics students. Several tests have been developed to assess visualization abilities including the Purdue

Spatial Visualization Test[1] and the Mental Rotations Test[2]. Yue[3] considered visualization skills at various educational levels and found that visualization improved steadily with higher educational level. Little work has been done considering the assessment of engineering graphics concepts other than visualization. Recently, tests have been created to determine the abilities of students in all aspects of engineering graphics.[4,5] This paper focuses on what students know about all aspects of engineering graphics upon starting and completing a college-level course.

The work presented here follows the progress of students throughout the entire semester, focusing specifically on their abilities before enrolling in the course. One objective is to determine the proficiency in engineering graphics of students upon entering the course. The work here also investigates whether students with previous engineering graphics experience learn anything new from the course. This research also examines if students without any prior engineering graphics knowledge learn the necessary information. Finally, the pace of the course is examined to determine if the course is too slow for students with prior experiences or too fast for students without any previous experience.

This paper begins with an outline of the engineering graphics course and the methods in which it is delivered to students. Next, the procedures used in analyzing the students abilities and their feelings on the course are discussed. Results from the investigation are then detailed. Finally, some conclusions are drawn from the research.

Course Structure

The engineering graphics course examined here was an introductory freshman-level course. The course was designed to transfer as the required engineering graphics course from a pre-engineering program to any bachelor-level engineering program. Consideration was made in the design of the course to ensure smooth transfer to both mechanical engineering programs as well as civil engineering programs, which often have different requirements for engineering graphics. The course is broken into three components: technical sketching, 2D CAD, and 3D CAD. In the technical sketching portion of the course, the general concepts of engineering graphics are covered including projections, visualization, dimensioning, and working drawings. This portion is not only designed to give students the foundation of engineering graphics before transitioning to computer drafting, but also gives students the skills needed to adequately sketch technical information by hand. Once the basic concepts are learned through sketching, the course transitions to 2D CAD followed by 3D CAD. Both 2D and 3D CAD are taught to ensure the course transfers to both civil and mechanical engineering programs. The specific 2D and 3D CAD packages used in this course are AutoCAD and Inventor, respectively. Three design projects were given to assess of the students' abilities in each of the course components. More details on the course structure can be found in the paper by Holdhusen.[6]

Two sections of this course were considered by this research. One section was a traditional face-to-face delivery of the course. The section met twice a week for two hours each meeting. The first 30 minutes of the class was spent introducing new material. The students spent the last 90 minutes of class working on a lab assignment with the instructor available to help with any problems. The other section was a hybrid course delivered to eight separate campuses. The first 30 minutes consisted of a lecture delivered through what is termed AudioGraphics. In this delivery mode, the instructor and the eight receiving sites connect via a teleconference and a Live Meeting via the internet. The lecture is live and the students can hear and respond to the instructor. In addition, the instructor controls what the students see through Live Meeting, such as a CAD program or a PowerPoint presentation. During the last 90 minutes, students work on a lab assignment, just as in the face-to-face section. While working in the lab, the students and the instructor log into a Breeze chat room on the internet. On this site, students and the instructor can instant message and the instructor can sketch or share his/her computer screen to demonstrate the CAD software, if necessary.

Procedures

Several methods were used to determine the students' abilities both before and after the course. Before the course began students were given a pretest to establish their abilities upon beginning the course. A similar posttest was given at the end of the course to determine what was learned from the course. In addition, a survey was given to students to get their perspectives of the course. Finally, two students with background in AutoCAD and Inventor were given small projects to determine their familiarity with the software upon starting the course.

The pretest was given the first day of class to establish the students' knowledge of engineering graphics at the beginning of the class. On the pretest, students were asked to describe their experiences in engineering graphics, if any. The rest of the test consisted of 25 multiple-choice questions. The topics in the test included projections (6 questions), visualization (5 questions), section and auxiliary views (5 questions), dimensioning (5 questions), and working drawings (4 questions). The same 25 questions were given at the end of the course to determine what the students learned. Students were required to include the last four digits of their social security number on the tests. That way, comparisons could be made between the each student's pretest and posttest while protecting the anonymity of the student.

The test used in this study was created by the author and its intent is to cover all aspects of engineering graphics. Several standardized tests have been created to assess visualization skills, including the Purdue Spatial Visualization Test[1] and the Mental Rotations Test[2]. However, the focus here was to determine the skills of students in all aspects of engineering graphics.

In addition to the posttest, a survey was given at the end of the semester to compile the students' thoughts about the course. Questions on this survey included what the students felt they learned, what their assessment was of the pace of the course, what their opinion was of the workload, and what their overall impressions of the course were. As with the pretest and posttest, students were asked to include the last four digits of their social security number so their engineering graphics experiences were known, as well as the results from the pretest and posttest.

Finally, two students from the face-to-face section with knowledge of AutoCAD and Inventor were given two small projects to determine their fluency with the software used in the course. The students were given a four-piece assembly and asked to create a set of working drawings in both AutoCAD and Inventor. These projects not only exhibited their knowledge of the CAD software, but also tested their knowledge of engineering graphics concepts like multiviews, dimensioning, and assemblies.

Results

The incoming experience level of each student in the class was determined first. Between the two sections considered in this research, 30 students participated in both the pretest and the posttest; 12 students were from the traditional face-to-face section and 18 students participated from the distance education section. Of the 30 students surveyed, 18 stated that they had some experience with engineering graphics or computer aided drafting software and 12 students did not have any previous experience with engineering graphics. Nearly all of the students with experience took some sort of course in high school. Most of these high school courses taught AutoCAD as the CAD software. A few students had courses that included 3D solid modeling software in addition to AutoCAD. These courses were evenly split between SolidWorks and Inventor.

Table 1 shows the results from the pretest and posttest for both the inexperienced students and the experienced engineering graphics students. The test questions are separated by topic: projections, visualization, section and auxiliary views, dimensions, and working drawings. The scores for each topic are shown in percentage of correct questions. For both student groups,

Table 1: Test question results for inexperienced and experienced engineering graphics students

	Projections	Visualization	Sections & Auxiliaries	Dimensions	Working Drawings	Total
Inexperienced						
Pretest	51.4	70.0	26.7	35.0	25.0	42.7
Posttest	81.9	76.7	48.3	76.7	75.0	72.0
Improved Questions	38.9	18.3	30.0	50.0	56.3	38.0
Worsened Questions	8.3	11.7	8.3	8.3	6.3	8.7
Total Improvement	30.6	6.7	21.7	41.7	50.0	29.3
Experienced						
Pretest	64.8	66.7	31.1	47.8	55.6	53.6
Posttest	87.0	81.1	63.3	73.3	83.3	77.8
Improved Questions	28.7	21.1	38.9	33.3	34.7	31.1
Worsened Questions	6.5	6.7	6.7	7.8	6.9	6.9
Total Improvement	22.2	14.4	32.2	25.6	27.8	24.2
Total						
Pretest	59.4	68.0	29.3	42.7	43.3	49.2
Posttest	85.0	79.3	57.3	74.7	80.0	75.5
Improved Questions	32.8	20.0	35.3	40.0	43.3	33.9
Worsened Questions	7.2	8.7	7.3	8.0	6.7	7.6
Total Improvement	25.6	11.3	28.0	32.0	36.7	26.3

inexperienced and experienced, the percentage of correct questions are shown for both the pretest and the posttest. In addition, the percent of questions on which students improved and worsened from the pretest and the posttest are shown. In effect, if a student missed a question on the pretest, but got that question correct on the posttest, they improved on that question. If they gave the correct answer on the pretest then missed it on the posttest, their performance worsened for that question.

As expected, the experienced students performed better than the inexperienced students on the pretest. The inexperienced student got 42.7% of the pretest questions correct, while the experienced students correctly answered 53.6% of the pretest questions. In particular, the experienced students did much better, 55.6%, on questions about working drawings than the inexperienced students, 25.0%. Interestingly enough, the inexperienced students performed slightly better, 3.3%, than the experienced students on problems covering visualization. While both groups performed the best on visualization questions on the pretest, previous engineering graphics experience seems to have no effect on the students' visualization skills.

The results from posttest revealed a total improvement of the entire class from 49.2% on the pretest to 75.5% on the posttest. The inexperienced students improved by 29.3% and the experienced students improved by 24.2%. In fact, every student improved from the pretest to the posttest except for one experienced student who performed 8% worse on the posttest. The best total improvement by a student was a 60% increase between the pretest and posttest. As expected, the inexperienced students showed greater improvement as compared to the experienced students; however the margin was not that significant. In addition, the margin between the posttest scores of the two groups was relatively small, 77.8% for the experienced students and 72.0% for the inexperienced students. Therefore, the students with prior experience in engineering graphics learned a similar amount from the college-level course as the students with no previous experience.

Students improved from the pretest to the posttest in each topic covered. The best improvement was in questions related to working drawings, while the least improvement was in visualization. The experienced students performed better than the inexperienced students in every topic except dimensions where the inexperienced student scored 76.7% and experienced students scored 73.3%. The inexperienced students improved the least on visualization, 6.7% increase from the pretest to the posttest. In fact, inexperienced students changed 11.7% of the visualization questions from the correct answer on the pretest to the wrong answer on the posttest. Also, students performed the best on visualization in the pretest and it dropped to third out of five on the posttest. The college-level engineering graphics course seems to have little effect on visualization skills of students. Note, the experienced students improved the most on sections and auxiliary views, 32.2% increase from pretest to posttest, while this topic was the second smallest improvement for inexperienced students, a 21.7% increase. While section and auxiliary views was still the lowest scoring topic on the posttest, there seemed to be an advantage in reviewing this topic for experienced students resulting in a dramatic improvement.

Statistical analysis was performed on the scores to determine the significance of the difference in scores in the pretest and posttest for both the experienced students and the inexperienced students. Table 2 shows the p values when comparing scores from different subject areas on the pretest and posttest for both experienced and inexperienced students. These p values were obtained from t tests. When the p value is greater than 0.05, there is no statistical difference in the data sets being compared. When comparing the scores of inexperienced and experienced students it is found that the experienced students outperformed the inexperienced students on the pretest. However, if the questions related to working drawings are removed, there is no statistical difference between the engineering graphics knowledge of the inexperienced and experienced student upon starting the course. After completing the course, the skill-level of the experienced students and the inexperienced students was statistically similar. Therefore, with the exception of knowledge of working drawings, there was little difference between the skills of inexperienced and experienced students both before and after taking the course.

Table 2: P values for each question type on tests for both experienced and inexperienced students

	Projections	Visualization	Sections & Auxiliaries	Dimensions	Working Drawings	Total
Inexperienced vs. Experienced						
Pretest	0.096	0.660	0.645	0.208	0.003	0.023
Posttest	0.249	0.550	0.087	0.661	0.336	0.122
Pretest vs. Posttest						
All	0.000	0.032	0.000	0.000	0.000	0.000
Inexperienced	0.001	0.394	0.047	0.002	0.002	0.000
Experienced	0.000	0.049	0.000	0.011	0.001	0.000

Table 2 also details the difference between the pretest and the posttest for both inexperienced and experienced students. The p value comparing the pretest and posttest for nearly all the types of questions was below 0.05. Therefore, regardless of previous engineering graphics experience, students improved from the pretest to the posttest. The one exception is visualization skills for inexperienced students. There was no statistical difference between the visualization scores on the pretest and posttest. In contrast, the experienced students showed significant improvement on visualization skills. It seems the more experience in engineering graphics students have, the better their visualization skills.

Another tool to determine the incoming knowledge of engineering graphics students was to have two students with experience with CAD software create a set of working drawings for a small assembly in both AutoCAD and Inventor. The students were able to create drawings in both programs and included the proper components for the set of working drawings. However, several mistakes were made in the creation of the detail drawings, particularly in AutoCAD. In using AutoCAD to create the drawings, the students did not properly use title blocks, they made errors in both overdimensioning and underdimensioning the detail drawings, and they had some misplaced hidden lines in creating the multiview projections. With Inventor, the students performed much better only struggling with the parts list on the assembly drawing. Inventor creates multiview projections automatically from 3D models and even automates the dimensioning process. However, these processes are done manually in AutoCAD and students struggled to create the drawings properly. These results coincide with the above results that experienced students performed worse than inexperienced students in dimensioning on the posttest. In addition, the poor creation of the multiview projections is consistent with previously discussed trouble the students had with visualization.

In addition to the posttest, a survey was given at the end of the course to get the students' thoughts on the course. In general, the course was well received by students. Nearly every student had a positive impression of the course. All but two students felt they learned new things from the course, regardless of their prior experience in engineering graphics. The majority of experienced students said they learned solid modeling in Inventor, which was not a part of their high school courses. A few experienced students even commented on learning more engineering graphics concepts through sketching. Sketching is an important aspect of engineering graphics that some students did not get from high school courses. One student stated, "[I learned] the proper way to do many things like the space between the dimension and the object [and other] things I took for granted with CAD because I never had to draw by hand before."

Two questions found from the survey concerned the pace and workload of the course. Table 3 details the results, in percentage of students, from these questions in the survey for both experienced and inexperienced students. The majority of students surveyed felt the pace and workload in the course were fine. None of experienced students felt the pace of the course was too slow. This demonstrates that the course was full of information from which even experienced students could garner new knowledge. A small percentage of students from both groups felt the pace was too fast, 23.3%. However, many of the students understood that the fast pace was necessary to cover every topic in the course. One student stated, "[The pace of the course is] kind of fast, but it needs to be fast so we stay on top of things."

Table 3: Inexperience and experienced student impressions of pace and workload

	Course Pace			Course Workload		
	Too Fast	OK	Too Slow	Too Much	OK	Too Little
Inexperienced	16.7	75.0	8.3	41.7	58.3	0.0
Experienced	27.8	72.2	0.0	27.8	61.1	11.1
Total	23.3	73.3	3.3	33.3	60.0	6.7

Another question from the survey was whether the workload was too much or too little. The results from this question are also outlined in Table 3. Again, the majority of students felt the workload was just fine. However, about one-third of students felt there was too much work in the course. In addition, 41.7% of the inexperienced students felt like there was too much work and none of them felt there was too little work. It was expected that the experienced students would feel the workload was more manageable, since they have some familiarity with the subject matter and the CAD software. Of the students that felt the workload was too much, some of them stated that the work was necessary to fully understand the material being presented. One student wrote, "The workload was heavy, but I can't think of a way to lighten the workload and still get the same knowledge of the software." Another student said, "The slightly higher workload helped to solidify skills quickly so they wouldn't be forgotten."

Conclusions

The research here investigated the experience level of students entering a college-level engineering graphics course and the effect that experience had on the performance in the course. A survey was given at the start of the course to determine what experience students had with engineering graphics. A pretest and posttest were given to both experienced and inexperienced students to determine what exactly they knew upon starting the course and what they learned from the course. In addition, two students were given small assemblies to create in AutoCAD and Inventor to determine their knowledge of the software. A survey was also given at the end of the semester to get the students' impressions on the pace, workload, and effectiveness of the course.

A majority of students had taken a high school course in which they learned AutoCAD. As expected, the students with previous engineering graphics experience scored better on the pretest than the students without any experience. However, if questions related to working drawings are neglected, there was no statistical difference between the performance of the experienced students and the inexperienced students on the pretest. Both groups improved from the pretest to the posttest and, as expected, the inexperienced students improved more than the experienced group. Therefore, it can be deduced that students learn something from college-level engineering graphics course regardless of their prior knowledge of engineering graphics. Unexpectedly, the inexperienced students scored better than experienced student in visualization on the pretest. In addition, both groups only improved marginally in visualization from the pretest to the posttest. In fact, there was no statistical difference in visualization on the pretest and posttest of the inexperienced students. Therefore, the college-level engineering graphics course has little effect on the visualization skills of students and should work to improve teaching those visualization skills. The second lowest improvement among inexperienced students was section and auxiliary views; however, this was the greatest increase in experienced students. Therefore, it seems that with more exposure, students gain a better understanding of section and auxiliary views.

Two students created working drawings of a small assembly using both AutoCAD and Inventor. The students performed well using Inventor; however, struggled in using AutoCAD to create the drawings. While they could use the functions of AutoCAD, they had trouble with creating the multiview projections and dimensioning. This shows a lack of understanding of the fundamental principles in engineering graphics, including projections, visualization, and dimensioning, as these concepts are done automatically in Inventor and manually in AutoCAD.

Nearly all students felt they learned something new from the course. The most common thing experienced students stated they learned from the course was 3D solid modeling. In addition, most students felt the pace and the workload of the course were good. Some of the students that said the pace was too fast or the workload was too much acknowledged that the pace and workload was needed to learn all the topics in the course. In conclusion, all students, regardless of previous experience, improved their test performance and gained new information from the college-level engineering graphics course.

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