

Student Achievement in Learning Computer-Aided Drawing and Course Content in Introductory Engineering Graphics Courses at North Carolina State University

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Abstract

The use of computers in technical graphics is requiring new approaches to graphics education. Because of this shift in course content, there was an interest in determining how students perform in these courses. Therefore, a correlational descriptive study was conducted in the Spring of 1999 to examine the factors of learning styles, major, prior computer experience, prior drafting experience, student classification, and gender in relationship to student achievement in learning CAD and course content. This paper will discuss the design of this study, the results of the analysis of the study data, and make some recommendations for further study and teaching practices.

Introduction

According to a survey conducted in the Fall of 1998 that investigated teaching practices in the field of engineering/technical drawing, 92.8 percent of the respondents indicated that some form of computer-aided drawing is being taught at their institutions (Clark & Scales, 1999). With the addition of computer-aided drawing to engineering/technical graphics courses, there is a need to find ways to fully integrate computer instruction into classes in an efficient and effective manner (Chipman, 1993). In order to create effective computer learning activities and design courses that deliver computer instruction along with engineering/technical graphics concepts to student with different characteristics, research must be conducted. However, an examination of the literature reveals that limited research exists on factors that affect students' achievement in learning to use technical graphics software and technical graphical concepts together.

Students in introductory Graphic Communications courses at North Carolina State University (N.C. State) come from different backgrounds and have different prior experiences. As a course that can be taken to fulfill the university's general education requirements, it also has students from a variety of majors. It has been observed in these classes that some students are less successful than others in developing the skills they need to use AutoCAD to produce acceptable models and drawings and in understanding the graphic concepts taught in the course. Although strategies used at N.C. State are fairly common for programs of this type (Clark & Scales, 1999), there is a need to examine factors that might affect the achievement of students in learning computer-aided drawing and the engineering/technical course concepts in these classes. This descriptive, correlational study explored the relationship between learning styles, major, prior computer experience, prior drafting experience, student classification, and gender on achievement in learning to use the computer-aided drawing package known as AutoCAD Release 14, and the concepts of technical graphics in introductory classes of engineering/technical graphics at N.C. State.

Design of Study

The study was designed as a descriptive correlational study (Borg & Gall, 1989) and used three dependent variables and seven independent variables. The subjects were from intact classes. Because it was a descriptive study, a control group was not used.

Seven independent variables were analyzed using Kendall's Tau B and multiple linear regression models. These included gender, major, student classification, the pretest score, learning style, the final exam grade, and the final exam grade with the posttest questions removed. For the analyzes, the variable of gender was classified as females (1) and males (2), and majors were combined into two categories of non-engineering (1) and engineering (2). For the Kendall's Tau B correlations, the independent variable of computer experience was categorized as: none (1), some experience (2), fairly experienced (3), and very experienced (4). For the multiple linear regression models, the computer experience categories were combined into some and fairly experienced (1) and very experienced (2). The level of student computer experience was self-reported. For the Tau B correlations, the variable of student classification used the categories of freshmen (1), sophomores (2), juniors (3), and seniors (4). For the multiple linear regressions these categories were combined into freshmen and sophomores (1) and juniors and seniors (2).

The dependent variables used in the study were the student score on the final project, the student score on the 10 questions that formed the AutoCAD portion of the final exam (posttest), and the final course grade. The posttest primarily provided a measure of students' knowledge of the names and functions of the commands in AutoCAD. The final project grade provided a measure of students' ability to use the commands and apply appropriate strategies for producing a drawing in AutoCAD. The final course grade provided a measure of achievement in learning overall course content. Final course grade was based on the homework assignments, two quizzes, a final exam, attendance, and the final project grade.

The target population for the study included students enrolled in introductory classes of engineering/technical graphics at N.C. State. These classes provide instruction in graphic concepts and the use of AutoCAD Release 14. The sample consisted of two sections of GC 120, Foundations of Graphics, taught during the Spring of 1999. The sections chosen to participate in the study had the same instructor to eliminate the instructor effect. The anticipated sample size was 48; however, due to a lower enrollment in one section, the beginning sample size was only 43, and subject attrition reduced the sample size to the 38 subjects used in the study analyses.

The instrument used to measure student learning style was the Group Embedded Figures Test (GEFT). This test measures a learner's use of an analytical or global approach to learning, which Witkins, et al. (1971) referred to as field-independent and field-dependent, respectively. Individuals who are field-independent process information analytically and have the ability to isolate individual elements from the context in which they are contained. Individuals who are field-dependent process information globally and relate elements to the context in which they are contained.

Part of the subjects' instruction in the use of AutoCAD consisted of completing six tutorials created for AutoCAD Release 14. The tutorials were designed to be delivered to students through the World Wide Web and had been used for a summer session and a semester before the study.

The questionnaire that each subject was asked to complete supplied data and information for a number of variables including the subject's demographics. The information included the subject's name, gender, and current classifications (Freshman, Sophomore, Junior, or Senior), major, level of prior computer experience, how computer experience had been obtained, if they had prior drafting experience, and computer courses taken.

A pretest, to test students' prior knowledge of AutoCAD commands and their functions, was administered at the onset of the study. The 10-question pretest on AutoCAD was developed by the researcher and tested for content validity, face validity, and accuracy by expert members of the Graphic Communications Faculty at N.C. State and a set of four students who had taken the GC 120 course. The pretest was designed to be similar to the posttest administered as part of the final exam. The questions for both pre and posttest were selected from a bank of AutoCAD questions created by the Graphic Communications' faculty. The 10-question portion of the final exam was used as a measure of students' knowledge of AutoCAD commands. These questions were reviewed by instructors in the Graphic Communications program for accuracy and face validity, and had been used for four semesters and four summer sessions as part of the course's final exam. Using the split-half method, a reliability estimate of 69% was obtained for the posttest (Gronlund, 1981).

Two methods of analysis were used in the study. A nonparametric analysis procedure, Kendall's Tau B, was used to correlate the variables. In addition, appropriate variables were included in three linear regression models. Model 1 examined the ability of certain independent variables to predict project scores, Model 2 examined the ability of certain independent variables to predict scores on the posttest, and Model 3 examined the ability of certain independent variables to predict the final course grade. A p-value of .05 or less was used in the analysis of the data to indicate statistical significance.

Research Procedure

The research was conducted during the 1999 Spring Semester. Two sections of GC 120 (Foundations of Graphics) were selected before the semester began. During the first week of classes, the researcher explained the study to the students, and asked them to participate. During the second week of the semester, prior to any AutoCAD instruction, the researcher administered the 10 question AutoCAD pretest, the research questionnaire, and the Group Embedded Figures Test (GEFT).

For the remainder of the semester, the participants proceeded through the course normally. Instruction in the use of the AutoCAD software for these sections included the six tutorials for AutoCAD Release 14, class demonstrations, and in-class and homework assignments. The AutoCAD instruction was designed to parallel the main course content. Instruction in the other course content was delivered as lectures, class demonstrations, and in-class and homework assignments. The final project assignment was to create a complex three-dimensional solid model in AutoCAD, convert it to a multiview drawing, add a titleblock, and dimension it according to the standards established by the American National Standards Institute (ANSI). At the end of the semester, the instructor provided the researcher with the students' grades on the final project, final exam, the posttest, and the course.

Research Results

Thirty-eight students participated in the research study, eight females and 30 males. The number of males and females in the sample was typical for the GC 120 classes. Students in the study included four freshmen, 20 sophomores, eight juniors, and six seniors. Students in the sample were from 19 different majors. Eighteen of the students were enrolled in engineering programs (14 males and four females) and 20 in non-engineering programs (16 males and four females). The nearly equal division between engineering and non-engineering students was typical for this course because of its General Education Requirement (GER) designation.

Tau B Correlations

One of the two dependent variables used in the analysis of the data to measure achievement in learning computer-aided drawing was the final project grades. The mean of the final project grade for the total sample was 88.81 (SD = 9.75), the mean for the 30 males was 91 (SD = 7.35), and the mean for the eight females was 80.6 (SD = 13.47). The analysis of the data indicated that the project grades were slightly negatively correlated with gender ($\tau_b = -0.346$, $p = 0.018$) due to the lower project grades of the females when compared to those of the males. A correlation found between the project grade and the final grade with the project grade removed ($\tau_b = 0.366$, $p = 0.003$) suggested that achievement in the general course content may be related to achievement in learning CAD.

An examination of the correlation analyses between project grade and other variables for the females in the study revealed a statistically significant correlation between the project grade and the females' prior drafting experience ($\tau_b = 0.707$, $p = 0.039$). The mean of the project grades for the females with prior drafting experience (N = 2) was 92.5 (SD = 3.54), and the mean of the project grades for the females without drafting experience (N = 6) was only 75 (SD = 14.14). For the females without prior drafting experience, the project grades ranged from a low of 50 to a high of 85. Examination of the same correlations for males as a group found slight significant correlations between the variables of project grade and the final grade with the project grade removed ($\tau_b = 0.332$, $p = 0.017$) and the project grade and the pretest score ($\tau_b = 0.339$, $p = 0.023$).

The posttest, a subset of the final examination, was the second dependent variable used to measure achievement in learning computer-aided drawing. The mean of the posttest scores for the total study sample was 7.63 (SD = 1.36), the mean of the posttest scores for the males was 7.63 (SD = 1.37), and the mean of the posttest scores for females was 7.62 (SD = 1.04). For the whole sample a weak correlation was found between the posttest and pretest scores ($\tau_b = 0.228$, $p = 0.084$), but it was not statistically significant. For the females, fairly large correlations were found between the posttest score and prior computer experience ($\tau_b = 0.516$, $p = 0.129$) and between the posttest score and the exam grade with the posttest score removed ($\tau_b = 0.491$, $p = 0.099$), but these correlations were not significant. The only significant correlation was for males between the pretest and posttest scores ($\tau_b = 0.316$, $p = 0.034$).

The last dependent variable, the final course grade, was based on graded homework, practice homework, two quizzes, a final exam, attendance, and the final project. For the whole group, a significant correlation was found between the final course grade and the final exam grade ($\tau_b = 0.444$, $p = 0.0001$). Slight, but non-significant, correlations were also found between the final grade and gender ($\tau_b = -0.263$, $p = 0.053$), the final grade and drafting experience ($\tau_b = 0.228$, $p = 0.093$), and the final grade and major ($\tau_b = 0.227$, $p = 0.096$). The negative value of the correlation between the final grade and gender was an indication that the females in the sample had lower course grades than the males. For the females as a group, a fairly large, but non-significant correlation was found between the final grade and prior drafting experience ($\tau_b = 0.546$, $p = 0.096$). When examining the males as a group, the final course grade was found to be significantly correlated with the final exam grade ($\tau_b = 0.416$, $p = 0.002$).

The questionnaire given to the subjects at the beginning of the semester asked them to rank their previous computer experience under one of the following categories: none (1), some experience (2), fairly experienced (3), or very experienced (4). Subject responses to this question ranged from some experience (2) to very experienced (4). The mean of the prior computer experience scores for the total sample was 2.92 (SD = 0.78), the mean for the females was 2.36 (SD = 0.51), and the mean of the males was 3.06 (SD = 0.78).

An examination of the means for computer experience by student classification revealed that sophomores reported the highest level of computer experience and seniors the lowest. The mean for each student classification was: freshmen = 2.75, sophomores = 3.15, juniors = 2.86, and seniors = 2.33. When examining computer experience by major, the engineering students as a group reported they had more experience. The mean for engineering majors was 3.11 (SD = 0.68), and the mean for non-engineering majors was 2.75 (SD = 0.85). The analysis of the data found a significant correlation between prior computer experience and gender ($\tau_b = -0.344$, $p = 0.027$). The negative value for this correlation was due to the females' lower level of reported computer experience when compared to the males.

Responses to the questionnaire indicated that exactly 50% of the subjects, 17 males and two females, had prior drafting experience. Only slight and non-significant, correlations were found for the whole group between this variable and others. For females, other than the non-significant correlation discussed earlier between prior drafting experience and the final grade, the correlations between prior drafting experience and other variables found correlations with major ($\tau_b = 0.577$, $p = 0.127$) and the Group Embedded Figures Test scores ($\tau_b = 0.492$, $p = 0.155$), but these correlations were not significant. When the same data for males were examined, only a slight, non-significant correlation was found between prior drafting experience and the Group Embedded Figures Test score ($\tau_b = 0.219$, $p = 0.180$).

The students' scores on the Group Embedded Figures Test ranged from two to 18, with a mean of 14.65 (SD = 4.04) and a median of 15.5. The interquartile range was from 13.75 to 17.25, and the sample distribution was skewed to the left. The mean of the males' GEFT scores was 14.53 (SD = 4.17), and the mean of the females' scores was 15.125 (SD = 3.75). The majority of the students' scores ranged from 12 to 18, and the mode was 18. The sample contained four field-dependent students (three males and one female), and 34 field-independent students. High GEFT scores were correlated with high final exam grades ($\tau_b = 0.299$, $p = 0.013$) and with high final exam grade with the posttest scores removed ($\tau_b = 0.367$, $p = 0.003$).

For the females in the sample, fairly large, but non-significant, correlations were found between high GEFT scores and high pretest scores ($\tau_b = 0.473$, $p = 0.161$) and between high GEFT scores and major (engineering or non-engineering) with a τ_b of 0.586 ($p = 0.091$). Females in engineering programs scored higher on the GEFT than those in non-engineering programs. The relationship of the Group Embedded Figures Test scores and the same variables for the males found a relationship between high GEFT scores and high final exam grades ($\tau_b = 0.407$, $p = .003$) and between high GEFT scores and high exam grades with the posttest scores removed ($\tau_b = 0.447$, $p = 0.001$).

The students' scores on the pretest ranged from three to nine with a mean of 5.94 (SD = 1.48) out of a possible 10. The mean on this test for the females was 6.37 (SD = 0.74), and the mean for the males was 5.8 (SD = 1.62).

The analysis of the data related to gender revealed slight but significant relationships between gender and the variables of final exam grade ($\tau_b = -0.330$, $p = 0.016$) and the final exam grades with the posttest score removed ($\tau_b = -0.298$, $p = 0.031$). Their negative values indicate that the females received lower grades than the males on both the exam and the exam with the posttest score removed.

Multiple Linear Regression Models

Three models were created to look at student achievement, two for achievement in learning computer-aided drawing and one for achievement in learning the course content. The dependent variable for Model 1 was the project grade, for Model 2 the posttest score, and for Model 3 the final course grade. In developing the multiple regression models, the information from the Kendall's Tau B analyses and backwards stepwise regressions were employed to identify the independent variables for the final models. Possible interactions between variables were also examined to see if the models could be improved, but no significant interactions were found. For the multiple linear regressions the student classifications were combined into two categories of 1 (freshmen and sophomores) and 2 (juniors and seniors), and the prior computer experience ratings were combined into two categories of 1 (some experience and fairly experienced) and 2 (very experienced). The category of none for computer experience was not selected by any of the subjects.

The independent variable in Model 1, to predict Project Score, include of gender, pretest score, and major (engineering or non-engineering). Table 1 summarizes the model's parameter estimates.

Table 1

Model 1 (Project Grade) - Parameter Estimates for Final Model (N = 38)

Term	Estimate	Std Error	t Ratio	Prob.> t
Intercept	86.799942	7.434604	11.68	<.0001
Gender	-11.40167	3.401663	-3.35	0.0020
Pretest	1.6428794	0.949645	1.73	0.0927
Major	4.1033636	2.761346	1.49	0.1465

The coefficient of multiple determination (R^2) for Model 1 was 0.310, which indicates the proportion of the variation in the project grades that can be explained by the predictive power of the independent variables of gender, pretest score, and major (engineering or non-engineering). The predictive power of this model was relatively good and the p-value for the final model's fit was 0.005, well below the p-value established for statistical significance in the study. The multiple linear regression formula for this model was: Predicted Project Score = $86.80 - 11.40X_1 + 1.64X_2 + 4.10X_3$ (X_1 = gender, X_2 = pretest score, X_3 = major). An examination of the data for the partial correlations revealed that only gender had a statistically significant p-value. The independent variables of pretest score and major were not significant in the model, but had p-values below 0.15.

The dependent variable in Model 2 was the posttest score. Table 2 summarizes the model's parameters. The independent variables used in the final model were pretest score, GEFT score, and final exam grade with the posttest removed.

The coefficient of multiple determination (R^2) for Model 2 was only 0.196. The p-value for the model's fit was 0.056, slightly above the established level for statistical significance. The model obtained from the multiple regression analysis provided the following formula: Predicted Posttest Score = $3.77 + 0.35X_1 - 0.13X_2 + 0.05X_3$ (X_1 = pretest score, X_2 = GEFT score, X_3 = exam minus posttest grade). The table listing partial coefficients with other variables held constant (see Table 2) revealed that two independent variables, the pretest scores ($p = 0.021$) and the GEFT scores ($p = 0.048$), were statistically significant in this model, but the p-value of the exam grade minus the AutoCAD questions was not.

Table 2

Model 2 (Posttest Score) - Parameter Estimates for Final Model (N = 38)

Term	Estimate	Std. Error	t Ratio	Prob.> t
Intercept	3.7741623	2.246502	1.68	0.1021
Pretest	0.3526768	0.145956	2.42	0.0212
GEFT	-0.126328	0.061523	-2.05	0.0478
Exam-Post	0.0496353	0.031129	1.59	0.1201

Model 3 used the final course grade as its dependent variable, and the three independent variables of gender, the Group Embedded Figures Test score, and student classification. Table 3 provides the model's parameter estimates.

Table 3

Model 3 (Final Course Grade) - Parameter Estimates for Final Model (N = 38)

Term	Estimate	Std. Error	t Ratio	Prob.> t
Intercept	79.482384	5.565844	14.28	<.0001
Gender	-4.739248	2.432044	-1.95	0.0596
GEFT	0.4276866	0.248455	1.72	0.0943
Class	3.4253462	2.027521	1.69	0.1003

The R^2 for Model 3 was 0.211. The multiple linear regression formula for the final model was: Predicted Final Course Grade = $79.48 - 4.74X_1 + 0.43X_2 + 3.43X_3$, (X_1 = gender, X_2 = GEFT score, and X_3 = student classification). The partial coefficients with other variables held constant, reveals that none of the independent variables was statistically significant in this model. The p-value for gender, however, was only slightly above .05 ($p = 0.059$). The Group Embedded Figures Test scores ($p = 0.094$) and student classification ($p = 0.100$) had p-values that were higher, but still small enough to be included in the model.

Discussion

When examining the findings of the study, there are some things of note, but the only strong relationship found was between the females project grade and prior drafting experience. Most of the larger correlations found were related to the females or gender, but many of these had p-values that were slightly above statistical significance due to the number of females in the study. With only eight females out of 38 subjects, it is inappropriate to draw any real conclusions from these correlations. The data suggest that females in introductory engineering/technical graphics classes at N.C. State may have a lower level of prior drafting experience, less prior computer experience, and do not do as on the final project as males. The data suggest that all of these could be connected.

The large difference in the males' and females' mean project grade was not anticipated. Unfortunately, the lower mean for the females could be due to one or a combination of factors examined in the study. These include a poorer understanding of the computer-aided drawing program, a lower level of previous drafting experience, or a lower level of previous computer

experience. It is also possible that other factors, not examined in this study, may have caused or contributed to the difference. For instance, females typically have poorer visualization skills compared to males, which could have affected the project grade (Parolini, 1994).

In introductory engineering/technical graphics courses at N.C. State, students construct the projects as three-dimensional computer models, and the CAD program extracts the multiviews from the models. The construction of a computer model is reminiscent of building an object from solid materials. Experience with students seems to indicate that students find model construction far easier than traditional multiviews. It also seems that that students do not need strong visualization skills in order to create them (Crittenden, 1999). Experiences assembling and disassembling objects probably would also aid in building computer graphics models, and there is some evidence that females do not have as much experience as males doing this (Deno, 1995).

Other factors that could have accounted for, or contributed to, the differences in the mean of the project grades for males and females were the females' lower levels of computer and drafting experience. The correlation coefficient between prior drafting experience and project grade for the females was the strongest one found in the data analyses, and would seem to be the best explanation for this difference. However, the same associations were not found in the males, so it would seem unlikely that this would have an effect on the project grades of the females and not on the project grades of the males.

The students' ratings of their previous computer experience may reflect the students' confidence in their ability to use computers rather than the level of their experiences since the computer experience score was based on a self-reported rating. The data analysis revealed a noticeably lower prior computer experience mean for the females when compared to the males. Although the literature indicated that females usually have less computer experience than males, females in the sample were majoring in technical and engineering programs and listed similar computer activities and backgrounds as the males on the research questionnaire. Levine and Donitas-Schmidt (1997) cited a study by Busch, conducted in 1995, in which he concluded that the only difference between males and females is their self-confidence and interest in computers. Gattiker (1990) and Shashaani (1997), however, found in their studies that the females performed better than the males in computer training courses.

The analysis of the relationship of learning styles and final exam grades found a correlation between the students' final exam grades and their GEFT scores. Since three of the four subjects who scored at eight or below on the GEFT were male, it is not surprising that the correlation was strongest when the data on the males were analyzed separately. Even stronger correlations for the whole sample, the males, and the females were found when the GEFT scores were correlated with the final exam after the posttest score was removed. These findings suggest a connection could exist between students' achievement on the technical graphics content of the course and the students' cognitive styles as measured by the Group Embedded Figures Test. These findings support the findings of Guster (1986), who found a relationship between GEFT scores and achievement for males in drafting classes in a high school. Another observation made during the analysis of the data was that the Group Embedded Figures Test scores of females and males in the sample did not differ. This agrees with research that indicates the proportion of males and females who are field-dependent and field-independent are essentially equal (Haaken, 1988; Cooperman, 1980). However, since the subjects used in the study were predominately from engineering and technical programs, and the number of females in the sample was quite small, this observation is merely interesting.

Recommendations and Summary

This study points to a number of areas that could be researched further. One possible area of study is the possible link between learning style and the students' achievement in the engineering graphics classes. If this association was substantiated, it could become a diagnostic tool to identify students who might have difficulty in grasping the concepts in the class, and allow instructors to make instructional modifications that accommodate these students.

Another area that warrants further investigation relates to the type of errors students make on the final projects. An analysis of these errors would provide information that could be used in eliminating instructional shortcomings and determining if the difficulties students have with the projects relate mostly to the CAD program or to the concepts in engineering graphics.

An examination of the characteristics of females enrolled in introductory classes in the Graphic Communications courses is particularly warranted. It is still not known whether the difference in the means for the reported levels of computer experience of the females and males was due to an actual difference in experience or a difference in confidence.

The change from constructing engineering drawings in two-dimensions to modeling them in three-dimensions requires a reexamination of visualization and gender issues. Whether females, when compared to males, are still handicapped by their lower visualization skills when creating solid models is a question that needs answering.

Based on this research study, several recommendations can be made for instructors in the field of engineering/technical graphics at the higher education level. Research indicates that females have less experience or less confidence in their ability to use computers when learning computer-aided drawing programs. Research also indicates that increased use of computers affects an individual's confidence in using them (Shashaani, 1997). Therefore, additional computer exercises may be needed to provide females with increased opportunities to interact with computers and software. These experiences should be designed to provide females with additional practice in creating solid models, in improving their visualization skills, and in functioning in three-dimensional computer space. The second recommendation relates to students' learning styles. Although students who enroll in introductory classes are predominately field-independent, this study indicated that field-dependent students who enroll in the classes do not achieve as well as their field-independent classmates. More attention should be paid to identifying these students, understanding their needs, and designing instruction that is appropriate for these learners.

This study is the beginning of an exploration into the nature of student achievement in learning computer-aided drawing and course content when they are taught simultaneously. It points to a variety of different research areas that should be of interest to instructors in the field of engineering/technical graphics. The teaching strategies of the past, when hand drawing was the core of technical drawing, may not be appropriate with the shift to computer-aided drawing and solid modeling. Without research, successfully instructing students in these new technologies is, at best, a shot in the dark.

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