Cooperative Learning as a Teaching Methodology within Engineering Graphics

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Abstract

Cooperative learning methodologies require that a positive interdependence exist between members of a group. This paper details a study conducted by the author on the utilization of cooperative learning within an engineering graphics course. Within the study, two sections were compared on computer-aided design (CAD) problem solving. The experimental section was taught utilizing cooperative learning methodologies, while the contrast section was taught using a traditional teaching approach. During class, students in the experimental section worked in groups on non-graded CAD problems while students in the contrast section worked individually. After each non-graded CAD problem, graded CAD assignments were given in which students from both sections worked individually. At the end of the semester, students from both sections were evaluated on their CAD problem solving ability.

Within this paper, the author explores cooperative learning fundamentals and different approaches to cooperative learning that can be implemented within engineering graphics courses. In addition, the author discusses the results of the study.

I. Introduction

Technological change has significantly influenced the fields incorporated in engineering technology. The area of engineering graphics is a good example of how an industry has been affected by this change. Just 20 years ago, a majority of all drafting was performed on a drafting board. With this traditional form of drafting, an engineer or an architect would design a product and the drafter, using drafting equipment such as paper, pencils, and a scale, drew the production drawings of the object that was to be constructed or manufactured. The final drawings would be distributed to contractors and manufacturing industries to build the product. Traditional board drafting, even though it could be very tedious, was not particularly technically challenging. Today, most drafting, including the design and development of a product, is done using a Computer Aided Design (CAD) system.

Technicians, such as drafters, are asked to work in environments that are changing and expanding constantly. Problems develop which must be solved. Technicians will be asked to solve these problems in situations where they will have little supervision. To be productive, a modern, “hi-tech” worker needs to have solid critical-thinking and problem-solving skills. Educational systems employed in teaching technology need to change to allow for the better development of these skills in students.

The ideal place to begin the development of problem-solving and critical-thinking skills is in education. A student receiving a technical education will receive training at an appropriate level to meet the needs of individuals and industries in a particular geographic location. This technological training, after being received by the student, will be valid only as long as the technology is current. What happens when new technology replaces old technology? Schools need to concentrate on the teaching of technological devices, such as CAD systems, but they also need to develop technicians who will remain technologically literate even after the technology has been replaced. When faced with a situation in which a technician must think through a solution to a problem, he or she needs to persist until the problem is solved. Remaining current in a technology is a matter of developing one's ability to think critically through problems encountered when working on a new technology. The problem is, how can technicians be trained in such a way that problem-solving skills and the desire to persist at finding solutions are developed? Cooperative learning is an educational tool that has been found to be successful at developing critical-thinking and problem-solving skills.

The purpose of this study was to compare the level of CAD problem-solving achievement between students who had been taught CAD by cooperative learning methods and those who had been taught by traditional individualized CAD teaching methods.

> Ho: When mean achievement scores on CAD problem solving are compared, there will be no statistically significant difference between students receiving instruction with cooperative learning methods from those students receiving instruction with individualistic teaching methods.

II. Cooperative Learning Theory

Cooperative learning is more than just allowing students to work in groups. Classes need to be structured to allow every individual in the group to contribute. The essence of cooperative learning lies in the design that requires students to contribute to each other's success. A state of interdependence exists in which each student has to rely on other group members in order to reach a desired goal. Johnson and R. Johnson (1994) list five essential elements of cooperative learning: (a) positive interdependence, (b) individual accountability, (c) face-to-face promotive interaction, (d) social skills, and (e) group processing.

A. Positive Interdependence

Positive interdependence is the first component to be implemented with cooperative learning groups. Unlike some teaching methodologies where students either compete against each other for class rankings or where they work alone to reach some individual goal, successful cooperative learning requires that the outcomes of one student be dependent upon the outcomes of all students in his or her group. No one group member is any more important than another. Each has a particular role to fill and the remainder of the group relies upon each individual in the group to accomplish his or her role. "Group members must realize that each person's efforts benefit not only that individual, but all other members as well" (Johnson, Johnson, & Holubec, 1993). If one individual is negligent in performing a task, the entire group suffers.

Johnson and R. Johnson (1994) and Johnson, Johnson, and Holubec (1993) describe three steps for structuring positive interdependence. First, there must be a clear and measurable task to perform. When performing a task such as solving a mathematical equation, writing a research report, or solving a chemistry problem, group members need to be aware of the standards that have to be met. Cooperative learning is easier to structure when there is an absolute right or wrong answer to a problem, such as in mathematics, but it can be used successfully for assignments which have a varying range from right to wrong. The key is to set a specific criteria or standard for the group to reach. Second, there needs to be positive goal interdependence. All members of a group need to work toward a specific criterion. To accomplish this, group goals and individual goals have to be set. In order to reach a group goal, the group as a whole has to rely on each individual to meet his or her individual goal. Third, positive goal interdependence needs to be supplemented with other types of positive interdependence. If a group is successful at reaching a goal, the group needs to celebrate. To help in the reward process, instructors, implementing cooperative learning methodologies, can reward group members with bonus points if all members of a group reach their individual goals.

B. Individual Accountability

According to Johnson and R. Johnson (1994), "individual accountability exists when the performance of each individual member is assessed ... and the member is held responsible by group mates for contributing his or her fair share to the group's success" (p. 86). It is important to remember the performance of individuals in a group when assessing the task outcomes of the group. Determining if a group obtained the criteria set for them is important, but it is equally important to determine if each individual met a prescribed level of performance. By measuring the level at which an individual performed, it can be assessed how well he or she contributed to the overall efforts of the group. It is important that no one individual is allowed to ride the efforts of the group without contributing equally in the educational process. Allowing for individual accountability in cooperative learning makes it essential for each group member to contribute equally toward the group goal. Johnson, Johnson, and Holubec (1994, p. 31) list five ways to structure individual accountability:

1. Allowing for smaller group sizes to ensure that each group member has the opportunity to contribute.
2. Examining each group member individually.
3. Recording the amount that each group member contributes toward the group goal.
4. "Assigning one student in each group the role of checker, who asks other group members to explain the reasoning and rationale underlying group answers" (p. 31).
5. Having students explain to the whole group what they have learned.

C. Face-To-Face Promotive Interaction

According to Johnson and R. Johnson (1994), "promotive interaction exists when individuals encourage and facilitate each other's efforts to complete tasks in order to reach the group's goals" (p.89). Too often, when groups are assigned to worked on a classroom assignment, tasks are divided up among the group members and each member individually works on his or her own particular portion. Effective cooperative learning calls for groups to meet "face-to-face" to work on assignments. This allows for encouragement in individual efforts while fostering positive interdependence and individual accountability.

Johnson and R. Johnson (1994) describe three steps to take to promote group interactions. First, time must be set aside for group meetings. The best time is in a structured classroom setting where an instructor can observe student interactions. Group meetings can be held after normal class times but students need to stay constantly aware of all group activities and record them. Second, the instructor should point out situations that involve positive interdependence. Making students aware of situations that are influenced by positive interdependence "creates the commitment to each others' success" (p. 89). Third, instructors should "encourage promotive interaction among group members" (p. 89). Successful learning through cooperative learning will not occur without face-to-face interaction between group members. Encouraging teamwork is critical.

D. Interpersonal and Small Group Skills

In order for cooperative learning to work effectively, group members must utilize certain levels of interpersonal skills. Being able to work in a group environment does not come naturally to all individuals. According to Johnson and R. Johnson (1994), "the greater the members' teamwork skills, the higher will be the quality and quantity of their learning" (p. 90). Students must do four things in order for cooperative learning to be successful: (a) students should get to know other group members and develop a trusting relationship, (b) students should communicate accurately and clearly, (c) students should provide support to other group members, and (d) students should solve disputes in a constructive matter (Johnson, 1991, 1993; Johnson & F. Johnson, 1994). Teaching teaming skills is an important component of cooperative learning.

Johnson, Johnson, and Holubec (1994) describe four "general rules" which govern the teaching of cooperative skills. First, "a cooperative context must be established prior to teaching cooperative skills" (p. 64). Students must be made aware up front that in order for them to be successful in a course, they must cooperate with other group members. Second, cooperative skills must be taught directly to students. It is not enough just to teach the fundamentals of social and cooperative skills. The teaching of cooperative skills should be placed in context with each lesson and reinforced when performed adequately. Third, group members determine whether cooperative skills are being utilized effectively. Instructors are there to set the stage for cooperative learning but it is up to each group to monitor the effectiveness of all individuals' cooperative skills, promote reinforcement of all positive social skills, and to provide feedback on group members' behavior. Fourth, the teaching of cooperative skills should occur as early as possible. Not only is it important to promote cooperation early in a prescribed class, cooperative skills need to be taught as early as possible in a child's education. In addition to this, cooperative skills should be taught at every level of education.

E. Group Processing

The final step in cooperative learning is group processing. Continuous improvement of cooperative teaching methodologies is made possible by evaluating the steps undertaken by groups while engaged in cooperative learning. Group processing serves as an "after-action-review" to find ways to improve the learning process. According to Johnson and R. Johnson (1994), group processing serves two purposes. One, group processing can be used to describe what went well and what needs to improve, and two, it can be used to make decisions about what to continue to do and what to modify.

III. Methodology

This study consisted of a randomized-posttest-contrast-group design. Students in the study were assigned randomly into either an experimental section or a contrast section. The experimental section was taught by cooperative learning methodologies where students were assigned to cooperative groups of four or five individuals for instructional purposes. The contrast section was taught by individualistic techniques of CAD instruction. At the end of the treatments, students were tested on their ability to solve a CAD problem. This test consisted of students being evaluated on a CAD problem similar in nature to problems given throughout the semester.

This study was conducted at Oklahoma State University in Okmulgee (OSU-Okmulgee), a state supported three-year technical institution. OSU-Okmulgee offers Associate of Applied Science degrees in such areas as Construction Technology, Electronic Engineering Technology, Manufacturing Technology, Food Service Management, Automobile Service Technology, and Business Administration. A typical program at OSU-Okmulgee requires 90 semester hours to complete.

The study's subjects consisted of students enrolled in the course ENGT 1023 "Computer Aided Drafting One" (CAD I) which was taught by the Engineering Graphics Technology Department. The majority of the students enrolled in this course were majoring in Design Drafting Technology, with CAD I being the first course required in the curriculum and acting as a prerequisite for all other courses. There were some students from departments outside of engineering graphics such as construction, electronics, and air conditioning-refrigeration. There were 28 males and 3 females involved in the study. The average American College Testing Program (ACT) score was 19.0 (SD = 3.44) with a low of 13 and a high of 25. There were 37 students enrolled in the course originally. Before the end of the study, one student tested out of the course, two students (one from the experimental section and one from the contrast section) stopped coming to class without withdrawing officially, and three students withdrew officially from the course.

The Engineering Graphics Technology Department and OSU-Okmulgee modified its normal course schedule to allow for the random assignment of students into two CAD I sections with an initial possible enrollment of 25 students per section. To do this, a section of CAD I was created with a maximum enrollment of 50 students. This course was scheduled for two hours per day, five days per week. A course of this nature is required to meet only five hours per week instead of the scheduled ten; but to allow for random assignment, students were required to enroll in all ten hours. Care was taken during the departmental schedule development process to make sure that no conflicts existed with other required courses. During the first week of the course, students were assigned randomly into either the contrast section or the experimental section. Randomization took place by assigning each student a number and then using a random numbers table to assign him or her to his or her respective section. The experimental section was picked randomly to receive the first student during the random assignment process. An instructor blind to the final purpose of the study taught both CAD I sections.

Students in the experimental section were assigned to formal cooperative learning groups of four or five students. Stratified random assignment was used to assign students to each cooperative learning group. ACT scores from all students were compiled and rank ordered with the median ACT score being 18. The students in the upper half of the class based on ACT score (19 and above) were numbered and placed in one pool and the remaining students were numbered and placed in a second pool. A cooperative learning group was obtained by assigning randomly a minimum of two students from the upper pool and two from the lower pool. The plan for the study was to not allow any individual group to drop below three students. The experimental section originally had 19 students enrolled in which four cooperative groups were derived. Within the first week of the semester, one student tested out of the course and one withdrew officially.

The contrast section was taught using an individualistic teaching methodology. Each topic began with a lecture over the material to be studied. The format of the lecture included demonstrations incorporating an LCD panel and overhead projector, chalkboard demonstrations of commands, and videotape presentations. The lecture methodology technique was determined by the course instructor but monitored closely by the researcher. A typical lecture lasted for one class meeting but occasionally ran into time scheduled for laboratory activities. Following a lecture, the class was given a non-graded CAD drawing assignment to complete. Students worked on this assignment in class with the help of the instructor. They were also allowed to receive help from other students if needed. If an assignment was not completed in class, the student had the option of finishing it outside of class. All non-graded assignments were turned into the course instructor for evaluation but not for a grade. Periodically, the class was given an assignment to be worked on for a grade. Each student individually worked this assignment without any help from the instructor or from any other student. This assignment was completed in one class period usually but occasionally, multiple class periods were used.

The experimental section was taught using cooperative learning teaching methodologies. The material covered by the experimental section and the assignments given, graded and non-graded, were identical to the material covered and assignments given to the contrast section. Each topic began with a lecture over the material to be studied. This lecture was identical in content and methodology to the lecture given to the contrast section. Following each lecture, a CAD drawing assignment was given to the class to be worked on in each student's cooperative learning group. This assignment was identical to the corresponding assignment given to the contrast section. Help could be received from other groups, if necessary. The instructor in the course was cautioned on the amount of help to give each group. The researcher monitored this closely. The amount of time allocated to the experimental section to work each assignment was the same amount of time given to students in the contrast section. Each group turned into the instructor one copy of the completed or partially completed assignment for evaluation but not for a grade. Periodically, the experimental class was given an assignment to work on for a grade. Each student worked this assignment individually without help from the instructor, from group members, or from other students. This assignment was completed in one class period but, like the contrast section, occasionally lasted multiple class periods. After each graded assignment, group scores were calculated by obtaining the average score of all individual grades in a group. If a group score was greater than 70 points on the first graded assignment, five additional points were awarded to each group member's individual score. Five points were added to the bonus cutoff score for each sequential graded assignment. As an example, the second graded assignment required a group score of 75 and the third a score of 80 in order to receive the bonus. The required bonus cutoff score did not rise above 90 points. Each group was then ranked according to its group grade. The group rankings were then published for the class to see without the group scores being visible. To improve on group processing, a discussion took place once per month to determine ways to better improve each group's cooperative techniques.

During the last two weeks of the semester, students were evaluated on their CAD problem solving ability. This evaluation was a drawing examination similar to the graded drawing assignments given throughout the semester in content and methodology. A team of four experienced CAD I instructors, including the researcher, developed the problem and the grading standards. The goal of this evaluation, when being developed, was to find an instrument to measure the CAD problem-solving achievement of students in an introductory CAD course. When all students completed the examination, the drawings from each section were coded by student number and sorted together. A faculty member with experience teaching CAD I, who was blind to the study's purpose, evaluated the drawings. A numerical score from 0 to 100 was given and the means for each section calculated. An Analysis of Variance was used to test for any statistical significant difference between the contrast section and the experimental section for CAD problem solving. It was conducted at an alpha level of .05.

IV. Results

Data on ACT scores, semester grade-point-averages (GPA), and total attendance time for each student were collected for use as descriptive statistics and as possible covariates (see Table 1). A total of 15 students per section participated in the CAD problem-solving examination. One student from the individualistic learning section was absent during this examination and did not participate in this portion of the investigation

[redacted]		ACT		GPA		Attendance*	
Section	N	M	SD	M	SD	M	SD
Cooperative Learning	15	19.73	3.37	2.42	1.13	50:00	11:58
Individualistic Learning	16	18.31	3.46	2.87	.95	51:22	8:46
*Note: Attendance values are measured in hours and represent the total amount of time that a student spent in class (The maximum attendance possible was 75 hours).							

Table 1: Average ACT Scores, Final Grade-Point-Averages, and Attendance for each Section

There was no significant difference between the two sections on ACT score, $t(29) = 1.157$, $p = .257$, final semester GPA, $t(29) = 1.209$, $p = .236$, or class attendance, $t(29) = .366$, $p = .717$ (see Table 1 for a summary). Of an additional note, there was a positive correlation between attendance and final semester GPA, $r(29) = .629$, $p < .01$.

Each student's ACT score, final semester grade-point-average, and total class attendance were obtained for use as possible covariates. Table 1 summarizes these values for each group. The purpose for planning for the use of a covariate was to reduce any differences between the groups resulting from sampling error and to reduce the within group variation. Using a Pearson Product Moment Correlation, neither the student's GPA ($p = .281$), their ACT score ($p = .063$), nor their attendance ($p = .062$) had a significant correlation. Without a suitable correlation between obtained variables, a covariate was not used in the ANOVA research design.

Levene's test for equality of variance revealed no significant difference ($p = .341$) between the two sections on the variance of CAD problem-solving scores. As shown in Table 2, the ANOVA failed to reject the hypothesis, $F(1, 28) = .233$, MSE = 80.03. There was no difference ($p = .640$) on CAD problem-solving achievement between the section receiving instruction using individualistic teaching methodologies ($M = 66.60$) when compared to those students receiving instruction using cooperative learning methodologies ($M = 63.33$).

Source	SS	df	MSE	F
Between Groups	80.033	1	80,033	.223
Within Groups	10042.933	28	358.676	
Total	10122.967	29		

Table 2: Analysis of Variance Summary Table for CAD Problem Solving

V. Discussion

The hypothesis of this study compared the effects that cooperative learning and individualistic learning teaching methodologies have on CAD problem-solving achievement. Previous research findings have shown cooperative learning to be a superior teaching method for improving achievement in mathematics (Norwood, 1995; Sherman & Thomas, 1986; Slavin & Karweit, 1984), science (Sherman, 1988), and computers (Johnson & Johnson, 1985; Johnson, Johnson & Stanne,1986). Cooperative learning has also shown to be a better way to improve problem-solving skills in students when compared with individualistic learning (Esdaille, 1996; Gokhale, 1995; Healey, 1993; Qin, 1992). In this study, there was no statistically significant difference in CAD problem solving when cooperative learning and individualistic learning techniques were compared. There was a small difference in the mean scores between the cooperative learning section ($\underline{M}$ = 63.33) and the individualistic learning section ($\underline{M}$ = 66.60). Even though previous evaluations of cooperative learning studies (Johnson & Johnson, 1989; Slavin, 1983) have shown large effect sizes to be common, this study produced only a small one (Effect Size = .01).

One interesting finding from the data was the difference in the variances of the two sections. Even though Levene's test for equality of variance did not show a significantly different variance ($\underline{F}$ = .940, $\underline{p}$ = .340), the observed difference between the variance for the cooperative learning section ($\underline{SD}$ = 22.71) and the variance for the individualistic learning section ($\underline{SD}$ = 14.20) should be noted. A review of the raw research data shows one potential outlier in the cooperative section (x_i = 5). The removal of this individual score would increase the mean score of the experimental section (adjusted $\underline{M}$ = 67.5) past that of the contrast section and even more important would lower the standard deviation (adjusted $\underline{SD}$ = 16.58).

The power of the statistics from the first hypothesis is extremely low for three important reasons. First, the variances in both sections are large. Large variances effect the size of critical values in statistical calculations (such as in an ANOVA and t-test) by increasing the denominator of the formula. Covariates are used often in ANOVA designs to reduce this within group variation. A lower within group variation will in turn increase the statistical power of a study. The original design of this study called for the use of a covariate to help reduce the within group variation but the researcher was unable to find a suitable one. The small effect size of this study precluded the researcher from continuing the search for a possible covariate since no amount of covariates would have eliminated the within group variation enough to obtain a significant difference. This leads to the final two reasons for low power. It is obvious that the means of the two groups ($\underline{M}$ = 63.33; $\underline{M}$ = 66.60) are close. The statistical results of the study showed that there were no differences between the two groups on CAD problem solving. The treatment, in this case cooperative learning, had no effect in increasing the size of the problem-solving scores for students in the study when compared to those students taught by individualized learning. According to Stevens (1990), an individual can increase the power of a study by increasing the effect size or by increasing the sample size. The only way to increase an effect size is by providing a treatment that is actually effective. In the case of this study, the group that received the experimental treatment actually had a smaller mean score. A significant increase in the sample size would result in a statistical difference between the sections but due to such a small effect size, this sample would have to be extremely large.

VI. Summary

Technology is changing the way that individuals function at work and at home. One would be hard pressed to walk through a modern house and not find some form of technological device in every room. The same statement can be said for business and industry. In addition, most jobs, especially those that require a college degree or some form of post-secondary training, have technologies such as computers that can be both invaluable and intimidating.

At one time, job skill requirements were fairly static. A problem with technology is that it is always evolving and increasing. Today, training and retraining are accepted practices of modern business. Likewise, industrial and corporate training are common functions of most large corporations.

With the continuous change in technology, a concern exists for making users feel comfortable solving problems with technological devices. Many times, when presented with a situation that is technologically challenging, individuals often give up or do not even attempt to solve the problem. Solutions to technical problems are usually easy to find, especially if one is willing to persist. If a solution to a problem is capable of being found, trying multiple approaches at solving the problem is often necessary. Eventually, through repeated attempts from different perspectives, a solution can be found. In addition, by persisting at finding a solution to a problem, individuals will naturally learn more about the technological system upon which they are working.

Cooperative learning has shown in previous research to be successful in developing problem-solving skills in mathematics and science and to improve self-esteem and interracial relationships (Cooper, Johnson, Johnson, & Wilderson, 1980; DeVries, Edwards, & Slavin, 1978; Johnson & Johnson, 1981). Cooperative learning involves students working in groups in an interdependent relationship to learn new material, solve problems, or accomplish course objectives. For cooperative learning to be successful, team members must rely upon each other. Johnson and R. Johnson (1994) describe five elements necessary for cooperative learning: (a) positive interdependence, (b) individual accountability, (c) face-to-face promotive interaction, (d) social skills, and (e) group processing. The key to cooperative learning is in establishing procedures that require students in a group to cooperate in the learning efforts of others in their group. This positive interdependence ensures that the success of one student is dependent upon the success of all students in his or her group.

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