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AUTHOR	Priebe, Roger
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ABSTRACT

This study compared the content comprehension and logical reasoning ability in two groups of second-semester university computer science students. The control group (n=25) received instruction in a traditional lecture/discussion learning environment three days a week for nine weeks. The treatment group (n=24) met in a cooperative learning environment for the same number of hours as the control group. Each group was given a pretest and posttest to measure levels of content comprehension and logical reasoning ability. No statistically significant differences were found with regard to content comprehension or logical reasoning ability; however, the experimental (cooperative) learning group did have a significantly higher attendance rate. In addition, other qualitative differences support many previous findings on cooperative learning environments. Contains 21 references. (Author)

The Effects of Cooperative Learning in a Second-Semester University Computer Science Course

Roger Priebe
The University of Texas at Austin
priebe@cs.utexas.edu

Abstract

This study compared the content comprehension and logical reasoning ability in two groups of second-semester university computer science students. The control group (n=25) received instruction in a traditional lecture/discussion learning environment three days a week for nine weeks. The treatment group (n=24) met in a cooperative learning environment (as defined by Johnson and Johnson, 1994) for the same number of hours as the control group. Each group was given a pretest and posttest to measure levels of content comprehension and logical reasoning ability. No statistically significant differences were found with regard to content comprehension or logical reasoning ability. However, the experimental (cooperative) learning group did have a significantly higher attendance rate. In addition, other qualitative differences support many previous findings on cooperative learning environments.

Introduction

Life is a cooperative effort. Every day we all depend upon others for food, companionship, and most of our basic needs. Even activities that seem to be competitive in nature —such as games or sporting events— ultimately become a form of cooperation as we agree to play by the same rules and maintain a common discourse. Gaining knowledge from our surroundings is a never-ending process that contributes to who we are and how we contribute to our society. Through this form of cooperation we define ourselves and are defined by others.

Although many of the world's activities are conducted cooperatively, the pedagogy used in higher education is quite often competitive or individualistic (Johnson, Johnson, & Smith, 1991). Teachers teach as they were taught (typically using a traditional lecture format), which makes change in academia a slow process! Although still not the norm, strategies for cooperative learning have been successfully used at the college level and are constantly challenging the current lecture-based learning paradigm (Purdom & Kromrey, 1995). This investigation examined how a cooperative learning environment affected students enrolled in a second-semester computer science class.

Statement of the Problem

Computer science is a highly complex and abstract subject matter. Many key concepts in computer science rely on students' formal reasoning skills. Toothacker (1983) found that only one-third of the entering university students were in Piaget's formal reasoning stage, another third could be classified as in the concrete operational stage, and a final third were in a transitional stage between the two.

Almstrum (1994) found that novice computer science students experienced more difficulty with concepts involving mathematical logic than more general computer science concepts. Kim (1995) concluded that propositional reasoning ability was related to course achievement in a logic class for computer science majors. Surprisingly, she also found that a logic course specifically designed to teach the logical concepts measured in the study did not improve the students' performance! One of her recommendations was to study new ways to teach introductory computer science courses, particularly the logic courses.

One interpretation Kim's (1995) findings is that the students who were her participants had not progressed far enough through Piaget's cognitive stages to understand the logic necessary for success in computer science. This theory is supported by the fact that students' skills in logic did not improve even though they were specifically being taught concepts in logic.

The attrition rates in the computer science major are quite high. Many students who struggle through the first few courses ultimately drop out of the major when the coursework becomes too complex. Much of this complexity is due to the increased amount of logic required for the courses. Could an attempt to create an atmosphere which fosters an improvement in logical reasoning skills improve the success rate for many computer science students?

Research Questions

What are the effects of cooperative learning on content comprehension, logical reasoning, and attendance in a second-semester computer science course? In particular:

- Will students in a cooperative learning environment comprehend computer science content better than students in a traditional lecture course?
- Will cooperative learning create an environment which helps students move through Piaget's cognitive stages and improve their logical thinking skills?
- Will a cooperative learning environment produce better attendance than a traditional lecture course?

Theoretical Foundations

Communication and Logic

Cooperative learning, by its very nature, causes an increased amount of communication. Most of this communication is verbal and the act of forming the words to explain a concept is very important. Vygotsky (1962) contends that the interrelationships between thought and language are a key to consciousness and therefore imperative to developmental changes. Instead of thought and language constituting two separate events, Vygotsky maintained the two are reciprocally implicated: the meaning in the thought is contained in the language and verbal communication enhances the thought process. His model of how learning occurs hinges on the learner taking small steps forward while being "scaffolded" through a *zone of proximal development* (ZPD) by others. This scaffolding is typically accomplished through verbal or written communication (Vygotsky, 1978).

Although not in total agreement, Piaget and Vygotsky both viewed intellectual improvements as qualitative and not quantitative. Quality of thought and the ability to gain new knowledge is more important than sheer amount of knowledge. This quality is expressed in Piaget's stage transitions. Further, the phases in the abstract reasoning stage are defined primarily by logical reasoning (Brainerd, 1978). Ultimately, my research is based upon the theory that increased communication in the cooperative learning environment spurs a qualitative change in students' thinking skills and moves them slowly forward into a higher plane of logical ability. A cooperative learning environment should foster behaviors necessary to move students through cognitive stages and hence improve their logical thinking skills.

McKeachie (1988) concludes that three of the most important activities that can increase students' thinking skills are student discussion, explicit emphasis on problem solving using varied methods and examples, and verbalization of methods and strategies to encourage the development of metacognition. These activities are all central to a cooperative learning environment; studies have shown that cooperative learning promotes a greater use of higher-level reasoning strategies and critical thinking than competitive or individualistic learning (Gabbert, Johnson, & Johnson, 1986; Skon, Johnson, & Johnson, 1981; Slavin, 1985).

The majority of research in cooperative learning has been done at the elementary and secondary levels. Interestingly, cooperative learning has not been heavily researched at the college level and particularly not in computer science (Johnson, et al., 1991). Mehta (1993) claims to have performed the first empirical investigation of cooperative learning in a college computer science course. Her findings were encouraging, finding a significant difference in test achievement between the control and experimental groups of students ($p \leq .01$). Other non-experimental research has been conducted in computer science using cooperative learning at the college level with generally positive results (Sabin & Sabin, 1994; Tenenberg, 1995; Yerion & Rinehart, 1995).

Experimental Design

The hypotheses in this investigation were tested by exposing the treatment group to a cooperative learning environment. The control group was given no treatment. This investigation is quasi-experimental (due to non-random sampling) and employs a pretest posttest control group design.

Population Sample

The population sample for the investigation consisted of the students enrolled in Computer Science 315 (CS 315) at a large southwestern research university during the summer term of 1996. CS 315 (the equivalent of CS2 at many universities) is a required course for computer science majors at this university. The course is typically taken as the second course in the computer science sequence. Students must have a grade of C or better in the prerequisite CS 304P (or equivalent) to enroll in CS 315.

The students in this sample all passed a first-semester course in computer science with Pascal programming (or an equivalent) and are considered representative of the population of second-semester computer science students at the university level. Several participants had previously taken CS 315 and not passed (or passed with a D, which is not sufficient for CS degree credit). These students were not excluded from the study because a truly representative population would also have subjects of this type. Of the 67 students originally registered for the course, 49 completed every data-collecting instrument (25 in the morning section and 24 in the afternoon section). Therefore, the content comprehension and logical reasoning portions of the study were conducted with a final total of N=49.

Control Group

The control group consisted of the students in the morning section of the CS2 course, which met three days a week for 90 minutes of class each day and one day a week for a 90 minute discussion. The control group was conducted using the traditional lecture/discussion method. Students in the control group were responsible for doing all programming and other assignments by themselves in an individualistic mode. The control group was given six programming assignments, three quizzes, two midterm exams, and a final exam.

Treatment Group

The treatment group consisted of the students in the afternoon section of the CS2 course, which met three days a week for 90 minutes of class each day and one day a week for a 90 minute discussion. The treatment group used a cooperative learning environment for all class instruction based upon the principles of cooperative learning described in Johnson, Johnson, and Smith (1991). The treatment group's discussion section was organized in the same fashion as that of the control group. The treatment group was given similar programming assignments and the same quizzes and exams as the control group.

Students in the treatment section were assigned to two types of groups: Heterogenous *base groups* consisted of four or five students selected on the basis of demographic data collected during the first class session. Base groups remained intact throughout the entire term, and were designed to provide academic and social support.

Most of the actual in-class coursework was completed in *working groups*, each of which consisted of three students. Working groups were formed prior to each of the term's three exams and dissolved after each exam. Each student was therefore assigned to a total of three working groups. To maximize the number of relationships formed, students were assigned to working groups heterogeneously with respect to base group membership and prior working group membership; no student was placed in a working group with another student from her or his base group or a previous working group. (An effort was also made to preserve heterogeneity with respect to demographic data.) Each working group completed one or two programming assignments and handed in one set of homework before each exam. All students in a given working group received identical grades on the programming assignments and homework; each student was individually responsible for his/her own test grade.

In a typical class for the experimental group, students began class by meeting in their base groups for five minutes to discuss any problems or other issues before them. Next, students broke into working groups to work on the problems covering material for the next exam. (Programming assignments were completed outside of class.) After about 20 minutes, the instructor gave a short (10-15 minute) lecture on a particularly important or difficult topic. After that, working groups reconvened and worked until the end of the class period.

Research Hypotheses

$H_0$1: There will be no difference between the cooperative learning and control groups in computer science concept comprehension.

Comprehension was measured using the Burton Comprehension Instrument (BCI) (Burton, 1992). This instrument was specifically designed for measuring the comprehension of five critical topics in the CS2 course: complexity, stacks, queues, recursion, and sorting. The overall alpha reliability of the instrument is 0.76 (Burton, 1992). The BCI was administered by giving the pretest portion of the BCI during the first week of class and inserting the prescribed test items into the final exam for both groups.

$H_0$2: There will be no difference between the cooperative learning and control groups in the improvement of logical thinking skills.

The Propositional Logic Test (PLT) was used to measure the students' logical reasoning skills (Piburn, 1985). The PLT has shown reliability ranging from 0.82-0.94 on high school and college students (Enyeart, 1980; Piburn, 1989; Kim, 1995). The PLT was administered once during the first week of class and then an alternate version, the A-PLT (Kim, 1995), was given during the last week of class.

$H_0$3: There will be no difference between the treatment and control groups in attendance.

- A headcount was taken each day of class. Students were not graded on their attendance or participation.

Results

Content Comprehension

A test for difference on the BCI posttest between the two sections was conducted using an Analysis of Covariance (ANCOVA). Table 1 shows the raw score means on the BCI pretest and posttest. Table 2 presents the ANCOVA results using the BCI pretest as the only covariate.

Because the test for homogeneity of group regressions was not found to be significant (F=.000, p=.989) the analysis of covariance could be continued. There was no significant difference found between the lecture and cooperative learning group in the area of concept comprehension (F= 0.530, p=.471). Therefore the null hypothesis $H_0 1$ is not rejected.

Table 1: Means and Standard Deviations for the BCI Pretest and Posttest

Group	N	BCI Pretest Mean	BCI Pretest Standard Deviation	BCI Posttest Mean	BCI Posttest Standard Deviation
Lecture	25	7.44	3.54	18.36	3.49
Cooperative Learning	24	8.29	3.43	18.86	3.48

Table 2: ANCOVA Result Comparing the Cooperative Learning and Control Groups on the Burton Comprehension Instrument (BCI) (N=49)

Source of Variation	SS	df	MS	F	Significance of F (p)
Within Cells	478.83	46	10.41		
By Class	5.51	1	5.51	0.53	0.47

Logical Reasoning

A test for difference between the cooperative learning and control groups on the PLT was conducted using a Multivariate Analysis of Variance (MANOVA) for Repeated Measures. The repeated measures over time consisted of the pretest and posttest for the PLT. Table 3 shows the pretest and posttest means and standard deviations. Table 4 presents the summary results of the MANOVA. No significant difference was found between the lecture and cooperative learning groups on the improvement in logical reasoning as measured by the PLT (F=2.00, p=.164). Therefore, the null hypothesis $H_0 2$ is not rejected.

Table 3: Means and Standard Deviations for the PLT Pretest and Posttest

Group	N	PLT Pretest Mean	PLT Pretest Standard Deviation	PLT Posttest Mean	PLT Posttest Standard Deviation
Lecture	25	11.12	4.43	13.2	3.79
Cooperative Learning	24	13.17	3.75	14.17	2.68

Table 4: MANOVA for Repeated Measures Result Comparing the Cooperative Learning and Control Groups on the Propositional Logic Test (PLT) (N=49)

Source of Variation	SS	df	MS	F	Significance of F (p)
Residual	167.92	47	3.57		
Class by Time	7.14	1	7.14	2	0.16

Attendance

A test for difference in the attendance between the cooperative learning and control groups was conducted using an Analysis of Variance (ANOVA). Table 5 presents the summary results of the ANOVA. A significant difference was found at the alpha level of .05 between the two groups (F=5.054, p=.030). Therefore, the null hypothesis $H_0 3$ is accepted.

Table 5: ANOVA Results on the Attendance Between Classes (N=23 lectures)

Source of Variation	SS	df	MS	F	Significance of F (p)
Residual	0.37	44	0.01		
Between Classes	0.04	1	0.04	5.05	0.03

Discussion

This study compared the content comprehension and logical reasoning ability in two groups of second-semester university computer science students. The control group (n=25) received instruction in a traditional lecture/discussion learning environment three days a week for nine weeks. The treatment group (n=24) met in a cooperative learning environment (as defined by Johnson and Johnson, 1994) for the same number of hours as the control group. Each group was given a pre- and posttest to measure the levels of content comprehension and logical reasoning ability.

Although no significant differences were found quantitatively, the character of the classes was certainly much different and qualitative differences were evident. The programming assignments and homework turned in by the cooperative groups was clearly neater and more complete than the individual assignments handed in by the control group. The researcher attributes these differences to an unwillingness to make everyone in the group look bad in the eyes of the instructor. In other words, *peer pressure*. This peer pressure may have also led to the significantly better attendance in the cooperative learning section of the course.

Another observed difference was the amount of after-class conversation. The students not only discussed the coursework, but engaged in a wide variety of school and personal conversation. The study of computer science at the university level is often a solitary pursuit. Students are often unprepared for the teamwork necessary in most working environments. This conversation was a very encouraging sign.

Very little direct instruction was performed in the cooperative learning group. Almost all of the course content for the exams and assignments was either peer-taught or self-taught. When given responsibility for their own learning, the students performed remarkably well. Quite often in larger universities, lower division and remedial courses are self-paced. The failure rates in these courses are typically quite high. Cooperative learning may work very well as a paradigm for such courses. The extrinsic motivational factors that exist in a cooperative learning environment would very likely help many students stay on pace and complete these courses successfully.

As past research has shown, cooperative learning can be very effective. Although this research experiment is inconclusive, this investigator would strongly encourage more research in cooperative learning at the university levels.

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Organization/Address: The University of Texas at Austin, Science Education, SZB 340, Austin, TX 78712

Telephone: (512) 471-7354

FAX: (512) 471-8466

E-Mail Address: priebe@cs.utexas.edu

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