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ABSTRACT

This study compared cooperative learning with individual learning in an introductory college electrical engineering course, using attitudinal and cognitive measures. Cooperative learning activities were implemented in homework assignments in one section of the course, while individual homework assignments were used in two other sections. A total of 79 students participated in the study, 19 of whom volunteered to enroll in the cooperative learning section. A 30-item questionnaire was administered at the beginning and again at the end of the course to assess the students' attitudes toward cooperative learning. Classroom observations, homework group observations, and individual interviews were used to assess cognitive factors. The results indicated that students in the cooperative learning section were initially more positively disposed toward cooperative learning than were students in the other two sections, but were more concerned about fairness in grading and workload as well. It was also found that students in the cooperative learning section significantly strengthened their belief that explaining problem-solving processes to others was an effective method for understanding or learning new material. An appendix provides a copy of the questionnaire. (Contains 44 references.) (MDM)

Application of Cooperative Learning in an Introductory Engineering Course

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Application of Cooperative Learning in Introductory Engineering Course

Introduction

College engineering education has made extensive use of both competitive and individualized instructional techniques for many years. Although these techniques have generally been successful, there is a growing feeling among engineering educators that modern engineering problems are becoming too complex to be solved in a timely and efficient manner by engineers working independently. In the real world of professional engineering, authentic engineering problems are increasingly solved by teams of engineers. Unfortunately, individualistic models of engineering instruction do not teach students how to interact with one another in order to work collaboratively to solve such problems. Recently, engineering educators have begun to explore the utility of cooperative learning as an alternative teaching method, one which may more effectively model the real world of professional engineering (Smith, 1988; Smith, Johnson, & Johnson, 1981). Much of the research on cooperative learning studies in college engineering education have tended to focus on comparing groups in terms of outcome measures such as academic achievement and course selection. Little attention has been paid in engineering education to the impact of cooperative learning activities on group processes and on student attitudes and beliefs about problem solving.

Goals of Engineering Education.

The primary goal of engineering education is to develop skilled, professional engineers who are capable of bridging the gap between science and the needs of society (Smith, 1988; Smith, et al., 1981). Smith, et. al (1981) identified three competencies engineers need to master in order to achieve these goals, technological competence, interpersonal competence, and socio-technical competence. Technological competence consists of (1) mastery and retention of science and engineering facts, principles, theories and analytical skills, (2) development of synthesis, design, modeling and problem solving skills; and (3) development of implementation skills for converting knowledge into action. Interpersonal competence refers to the development of cognitive, affective and behavioral skills needed for being able to work with others to accomplish a joint task. These skills include communication, interpersonal problem solving, joint decision making and perspective taking skills. Social-technical competence refers to understanding of the complex interdependencies between technology and society and of the influence of technology on individual and collective behavior on the natural environment. Recent evidence suggests that all three of these competencies, can be effectively promoted by the cooperative learning method (Lewis, 1991; Smith, et al., 1981).

Theoretical Background

Cooperative learning is a team effort to learning. Students work together to accomplish shared goals and are not finished with the work until all members of the group have learned. Research on cooperative learning in engineering education has shown it to foster a learning environment in which students learn to solve authentic engineering problems in real world situations and to simulate those kinds of activities in which professional engineers engage (Smith et al., 1981). Studies conducted on the effects of cooperative learning over conventional lecture-based technique have found positive effects on cognitive skills, metacognitive skills, and attitudinal measures (Archer-Kath, Johnson, & Johnson, 1994; Johnson, Johnson & Stanne, 1985; O'Donnell, Dansereau, Rocklin Hythecker, Lambiotte, Larson, & Young, 1985). Students working in cooperative learning groups have been found to retain factual knowledge better in a wide range of subject areas including scientific and technical material (Johnson, Johnson & Stanne, 1985; Lazarowitz, Lazarowitz & Baird, 1994; O'Donnell & Dansereau, 1992; Posner & Markstein, 1994; Yager, Johnson & Johnson, 1985), more effectively seek information from other students and produce more unbiased representations of problems (e.g., clarification or definition) (Brown & Palinscar, 1989; Johnson, et al., 1985; Schwartz, 1995; Schwartz, Black, & Strange, 1991; Slavin, 1991b).

Cooperative learning has also demonstrated improved acquisition of procedural knowledge (O'Donnell, et al., 1985). Further, students in cooperative learning groups show a tendency to elaborate problems better (e.g., able to more easily provide multiple examples) and to understand these problems better (Brown & Palincsar, 1989: O'Donnell, et al., 1985; Stevens, Slavin & Farnish, 1991) than students working alone. In addition, cooperative learning has been found to be effective in acquisition of important metacognitive skills such as self-monitoring and predicting activities (O'Donnell, et al., 1985; O'Donnell, Dansereau, Hall & Rocklin, 1987). Further, students in collaborative work outperformed peers working individually on discovery tasks (Okada & Simon, 1997).

Cooperative learning has also been found to be effective at fostering improved social cognitive skills such as interpersonal communication and joint decision making (Archer-Kath, et al., 1994; Johnson, Broker, Stutzman, Hultman & Johnson, 1985; Smith, 1988; Smith et al., 1981). Cooperative learning helps reduce fear of communicating with others by requiring students to talk with group members to solve engineering problems. In effect, students working cooperatively are encouraged to construct small learning communities. Then, they actively communicate with each other to negotiate and bring about consensus on solutions to the tasks on which they are working.

Finally, cooperative learning has been found to be effective at enhancing motivation to learn (Archer-Kath, et al., 1994; Klein, Erchul & Pridemore, 1994; Nichols & Miller, 1994), attitude toward the course content being studied (Johnson, et al., 1985) and the quality of interpersonal relationships among students (Lazarowitz, et al., 1994; Zahn, Kagan & Widman, 1986). Students in cooperative learning tend to spend more time on solving the tasks their groups are given (Johnson & Johnson, 1995). They not only recognize and evaluate themselves positively when working cooperatively (Lazarowitz, et al., 1994) but also socially tend to bond with others in the group (Archer-Kath, et al., 1994; Johnson & Johnson, 1981; O'Donnell, et al., 1987; O'Donnell & Dansereau, 1992). Further, cooperative learning has been found to have positive effects on other aspects such as improving classroom climate by increasing the number of positive, cooperative interactions, lessening anxiety and reducing tension (Johnson &

Johnson, 1995; Zahn, et al., 1986), helping to make compensatory education more effective with some minority students (dropout rate declined, selection of engineering as a career increased: Posner & Markstein, 1994), and improving quality of interethnic interaction (Johnson & Johnson, 1981). Few studies have examined whether such effects occur for engineering education.

Main Theoretical Themes of Cooperative Learning(CL)

The theoretical themes that developed in this section were mainly divided into four; cognitive, metacognitive, distributed expertise, situated learning aspects.

Cognitive aspects of CL. When a student engages in activities for solving problems, several cognitive processes are involved for those activities. The problem solving activities could be divided into four major activities; (1) perception of problems, (2) understanding problems, (3) solving problems, and (4) evaluating solutions. First, information stated in a problem is stored into one's working memory through sensory modalities of either visual or language mode. Cooperation with others may not provide much help students at this phase, because students bring their own prior experiences to perceive a problem. However, some advantages of cooperative learning over individual learning could be noticeable. For example, when one student reads a problem, other students may provide help to correct wrongly perceived information (Hinsz, Tindale, & Vollrath, 1997). O'Donnell and others (1985) demonstrated significant improvement in recall and retention of descriptive information through a cooperative work.

A second process of collaborative problem solving is to understand (represent) a problem utilizing prior knowledge and experiences (Hall, 1996; Moschkovich, 1996).

Understanding a problem means representing the current and goal state of the problem. In order to understand problems, students have to reconstruct problems using existing schemas. In other words, students have to retrieve appropriate schemas from long term memory for representing the problem on which they are working. These schemas consist of related procedural and declarative knowledge structures for solving problems. Cooperative learning is an effective way to help students recall appropriate schemas, because one can provide cues to others unless all students in a group do not have appropriate schemas. That is, there is a higher chance of recalling correct schemas when more than one student are working on the same problem.

However, it may also be true that if all students in a group do not have appropriate problem schemas, then cooperative learning has no advantage over individual learning. One reason why students with low ability do worse than higher ability students may be because they as a group have difficulty in applying correct schemas in problem solving. In addition, individual learners could face limited working memory capacity when they try to understand complex problems (Marcus, Cooper, & Sweller, 1996). If too many variables are involved in a problem, then limited working memory capacity could be a problem to students who are not expert problem solvers. In other words, it becomes difficult for one student to be able to understand whole problem. Engineering problems in real life are usually complex, but there are two ways of dealing with issues in classrooms by either simplify them or preserving their complexity. In order to preserve complexity as it is, cooperative work may be useful to overcome above problems such as lack of knowledge and working memory capacity (Koschmann, Myers, Feltovich, & Barrows, 1994).

A third phase of problem solving is to solve problems using operators. For example, mathematics problems could be solved using formulas and notational systems. In this process of problem solving, cooperative learning is effective in several ways. When students in a group are working on a problem, the problem is solved redundantly so that each student can check their problem solving procedure and mistakes during the process. Cooperative learning also reduces unnecessary cognitive load so that one can assign available memory capacity to do other activities. In order to solve a mathematically sophisticated problem such as electrodynamics problems used in this study, students usually require intensive efforts to maintain a high level of cognitive attention on the problem solving procedure to avoid making some potential errors (Reason, 1990). However, when students work together, they could divide their attention and use additionally available memory capacities for other tasks. This issue is related to metacognitive aspects of cooperative learning, which will be discussed in the next section.

Metacognitive aspects of CL. Metacognition refers to an awareness of one's own cognitive processing. In general, metacognition includes two components: knowledge about knowledge and self-regulation or monitoring (Flavell, 1979). As we described, sharing individual knowledge with others is a key advantage of cooperative learning. In addition, monitoring and self-regulation activities are also fundamental aspects of metacognition (Corno, 1986; Weinstein & Mayer, 1986). Monitoring activities are "executive" processes which activate and deactivate other cognitive activities as a function of the self- testing of thought processes as they occur (Pressley & Ghatala, 1990).

A few studies in the cooperative learning literature showed positive effects of cooperative learning on metacognitive skills. O'Donnell and others (1987) conducted a study to determine whether or not structured peer collaboration enhances learners' metacognitive skills. They reported that structured cooperation is more effective than unstructured cooperation. Metacognitive skills and strategies are crucial where the cooperative learning method is applied to engineering problem solving. First, students have to control information acquisition processes; tracking the information that students need and monitoring information by rehearsing and self-checking. Second, each student also has to monitor not only their understanding on a specific problem but also other students in a group when they engage in problem solving activities. Third, in the procedures of applying formulas and computations using tools such as text, computer or calculator, continuous error monitoring is required. Students have to check the intermediate answer with other students to get a correct final answer.

Distributed expertise in CL. Learning is a process that takes place in a participation framework, not in an individual mind. This means, among other things, that it is mediated by the differences of perspectives among the members of the learning environment (Lave & Wenger, 1991, p.15). In so far as "understanding" is something that a person does in his or her head, it ultimately limits learning experiences to the mental representations of each individual. Lave and Wenger (1991) reject the view that understanding is the mental operations of a subject on object structures in so far as they locate learning not in the acquisition of structure, but in the increased access of learners to participating roles in expert performances.

One of the major advantages of cooperative learning over individual learning is that any group will benefit from the increased range of expertise of its members' combined knowledge (Brown & Palincsar, 1989; Dunbar, 1995). Cooperative learning methods including peer collaboration are basically enhancing the notion of distributed expertise among communities of learners, although range of distributed expertise can be vary among cooperative methods. The "jigsaw" method, one cooperative learning technique, is regarded as an example which can create distributed expertise (Brown & Palincsar, 1989). This method creates extreme social-interdependence among learners. Each student is provided with only part of the materials of an academic unit but is evaluated on how well he or she masters the whole unit. One distinguishing characteristic of jigsaw method is the formation of expert groups. Each team member is assigned to an expert group composed of the members of other teams who have been assigned the same expert topic. The students meet in expert groups to exchange information and to master the material each student is to present to his or her team. Therefore, every student in a group has to become an expertise in their own materials.

Socially distributed intelligence also inevitably depends on the physical distribution of intelligence. For example, it is often advised that cooperative groups share a common workspace and resources, with one set of source materials for all the group members and one scribe to catch and organize the ideas of the group (Perkins, 1993). If the group develops a chart, there is one draft in front of all, a common focus around which the members interact. These kinds of artifacts created collaboratively enable them to communicate with each other (Latour & Woolgar, 1986). Thus, by participating in the practices of learning process, expertise can spread throughout within a group and classroom.

Situated learning in CL. Knowledge is not a fixed entity but situated in contexts. In other words, learning skills and knowledge are closely tied to particular contexts. Decontextualized or disembodied experiences replace true meanings with artificially created ones (Norman, 1993). That what happens in school mathematics, writing, or the study of history, bears little resemblance to what mathematicians, authors, or historians do is getting more attention among researchers.

The notion of situated learning has significant implication for the field of engineering education. Engineering as an academic field is connected to "pure science" such as mathematics and physics, or technical domains (Smith, 1988). However, there are clearly differences between engineering and pure science or technical facts. Expertise in engineering requires abilities to evaluate social needs and social skills so that they can communicate with other colleagues. Engineers have to not only learn scientific facts and knowledge, but also know how to apply those for real-life situations. In order for students to acquire the skills and knowledge used by professional engineers, they need to engage in similar cognitive activities-authentic tasks in authentic contexts. In general, engineers do not compete with each other to obtain solutions to problems. They must cooperate with others and coordinate activities so that each person involved is contributing skills and resources, due to the complexity of engineering problems which include both technical and social-technical elements (Smith, et al., 1981).

Cooperative learning creates a learning environment that professional engineers do solve problems in real world situations and students will involve in activities that professional engineers engage in during real problem solving situation rather than the artificially created processes.

Purpose of Study

The first purpose of this study was to compare cooperative with individual learning in an introductory engineering course, using attitudinal and cognitive measures. One issue of interest was the effect of cooperative learning on problem solving. Finally, we sought to describe at interactions among students in a cooperative learning class compared to those of students in an individualistic learning course.

Methods

Participants

Undergraduate engineering students enrolled in an introductory electrodynamics course at a large midwestern university were participants in this study. Cooperative learning activities were implemented in homework assignments for Section 1 of the course during the spring semester. In Sections 2 and 3, individual homework assignments were used. All three sections of the course were taught using a standard lecture format with assigned readings. Students in sections 1 and 2 were originally enrolled in a single section. Students who had enrolled in the course were solicited by email to volunteer to enroll in the experimental section of the course. There were 19 students in Section 1, 36 in Section 2, and 24 in Section 3.

Insert Table 1 About Here

The data in Table 1 indicate that there were few differences among the three sections of students before the course began. Students in section 2 did appear to have a slightly higher average GPA (3.3) compared to students in Section 1 (3.0) or Section 3 (2.9) but these differences were not statistically significant.

Procedures

Electrodynamics is an introductory electrical engineering course. Students have to finish this course successfully for their future career. The cooperative learning section of this course differed in that students were required to work together as a group to solve homework problems. Students in the other two sections were given the same problems but were not required to solve them in structured groups.

Formation of Teams. Teams of students in the cooperative section were formed by the instructor; students in the other two sections were not assigned to groups and were not encouraged to work cooperatively with peers to solve the homework assignments. In the cooperative learning condition, 3-4 students were assigned to a team. On each team, there were three designated roles: the coordinator, whose role was to make sure that all team members knew their responsibilities and understood all the subsequent problem solutions; a recorder whose role was to write out the final solution set; and one or two checkers (depending on the number of students on the team) whose roles were to check the solutions for accuracy before they were handed in. The instructor required that roles were rotated weekly, although the particular method of rotation was left to each team to decide. Students on the team received the same grades on assignments. All three sections had the same problem-based homework assignments and three exams (two midterms and one final).

Questionnaire. A 30-item questionnaire, developed to measure students' attitudes toward cooperative learning, was administered at the beginning of the course (pre-test) and again at the end (post-test). The internal consistency reliability (i.e., coefficient alpha) of the questionnaire was .84. A principal components factor analysis of the data from the first administration of the questionnaire (i.e., at the beginning of the course), suggested that there were three primary factors. Table 2 presents the 26 items which had loadings of .35 or higher on one of the three factors (items 11, 22, 27-3 and 27-4, which loaded on more than one of these factors were excluded). The first factor, attitude toward cooperative learning measure whether students view cooperative learning positively (e.g., I prefer to work on my homework in teams with other students). The second factor, course satisfaction, refers to items that measured general course-related concerns (e.g., I feel that I have been given enough information to be able to complete each homework assignment) which were not necessarily affected by experimental conditions. Items which loaded on the third factor appeared to measure a concern for fairness. This concern focused on whether each student in a group would have fair evaluation or that some students would have to work harder than others given that the assignments were group based (e.g., When students work together as a team on a homework assignment, some are likely to do more work than others).

Insert Table 2 About Here

In addition to these three factors, separate sets of items were used from the attitude factor to tap specific issues of concern: Item 16 asked whether students thought that working with others helped one's understanding of problems or of materials assigned for the class (e.g., I understand an assignment better when I work on it with others); Items 18 and 19 measured whether providing explanation to others helped one's own understanding (e.g., Explaining my solutions to others helps me understand the material better). Finally, students were asked to specify the number of hours of study time they spent working on homework or course readings outside of the classroom.

Observational Data. An important aspect of this study was to study students interactions outside the classroom and to specifically focus on the processes and mechanisms that were present in the homework groups (for the cooperative section). Three sources of qualitative data were gathered. First, classes for each condition were observed at least once a week. In addition to class observations, detailed observational data were also gathered from one group in the cooperative learning section. The group was observed at least once a week during the semester. Both written notes and audio tapes were used for collecting classroom and group observation data. These two sources of data are used and analyzed for two purposes; (1) to informally estimate baseline differences among the three sections and (2) to study the cognitive processes of collaborative problem solving in engineering domain. Finally, two students from the observed group were interviewed to see whether there were differences in students' perceptions on attitude toward cooperative learning.

Results

Analysis of Questionnaire Data

Analysis of the pretest questionnaire data revealed significant differences among the students in the three sections on the attitude toward cooperative learning, $F(2, 66) = 4.94$, $p < .01$. Post-hoc pairwise analyses indicated that students in the experimental cooperative learning were initially more positively disposed toward cooperative learning than students in the other two sections. Results from the post-test data demonstrated a similar significant difference among students in the three sections, $F(2, 50) = 3.65$, $p < .05$. Post-hoc pairwise comparisons using Fisher's Least Significant Differences (LSD) procedure showed that the cooperative learning section statistically differed with the other two lecture only sections. No difference was found between two lecture only sections.

Insert Table 3 About Here

Pre-test analysis showed no difference among three groups on the course satisfaction factor, $F(2,64) = 2.20$, $p = .12$. Analysis of post-test data, however, revealed a significant difference among the three sections, $F(2, 50) = 16.0$, $p < .01$. Pairwise post-hoc comparisons using Fisher's LSD procedure indicated that students in the cooperative learning section were significantly different than students in Section 3 but not Section 2. In addition, a significant difference was found between Sections 2 and 3. Figure 1 shows pre-test and post-test means on this factor. The means plotted in Figure 1 indicate that differences among the three groups were wider in the post-test data.

Insert Table 4 and Figure 1 About Here

Analysis of pre-test data revealed a significant difference among three sections on the third factor, concern for fairness, $F(2, 61) = 11.38$, $p < .01$. Post-hoc analysis indicated that students in the cooperative learning section were more concerned about fairness (or the "free rider" effect) which affect their grades or the amount of work they might be required to do. Analysis of post-test data revealed a similar difference on fairness among the three sections, $F(2, 52)$, $= 5.22$, $p < .01$. Post-hoc pairwise comparisons showed only a significant difference between the cooperative learning section and the other two lecture-only sections. No significant difference was found between the two lecture-only sections. Cooperative section students showed more concern about fairness of work assignment and grades than the other two sections. According to Figure 2, it seems that the fairness concern measure of the cooperative section did not change over time, while that of two other lecture sections showed a slight trend of an increase.

Insert Table 5 and Figure2 about Here

Analysis of the pre-test data for the set of items concerning "explanation" showed no significant difference among the three sections, $F(2, 71) = .93$, $p = .40$. Analysis of post-test data, however, revealed a significant difference $F(2, 51) = 3.61$, $p < .05$. Post-hoc pairwise comparisons indicated the cooperative section had a higher mean than Section 3. That is, students in the cooperative problem solving section significantly strengthened their belief that explaining problem solving processes to others are effective methods for understand or learning new materials (see Figure 3).

Insert Table 6 and Figure 3 about Here

Analysis of pre-test data for the set of items concerned with "understanding" revealed a significant difference, $F(2, 70) = 3.70$, $p<.05$. Pairwise post-hoc comparisons indicated that the cooperative section had a higher mean than either of the other two sections. These same results were found for the post-test data, $F(2, 52) = 3.39$, $p < .05$. No significant differences were found between the two lecture-only sections for either the pre-test or post-test data.

Insert Table 7 and Figure 4 about Here

Finally, analysis of pre-test and post-test data on amount of time spent studying showed no significant differences among the three sections.

Analysis of Qualitative Data

Interpretation of classroom data. Classroom data indicated no major differences based on teaching styles among three sections of electrodynamics classes. Instructors in all three sections used a standard lecture format including explanation of text material, providing examples, and asking questions of students in the class.

Although students in both cooperative and lecture only sections reported that there were no major differences among three instructors, observation of the three sections indicated some slight differences in lecture style of the three instructors. The primary difference was that the instructor in the cooperative learning section always wrote major points on the blackboard before class. In addition, he handed out notes for the class so that, if students chose to do so, they did not have to take notes during the class. The instructor in the cooperative learning condition was also somewhat more animated, exhibiting more energy during his lectures. Results from student interviews indicated that students were aware of this difference in lecture style. Students in the lecture-only sections said that the instructor in the cooperative learning section was known to be more animated.

Observational data indicated that the level of social interaction among students in the cooperative learning section was higher than among students in either of the lecture-only sections. Students in the cooperative learning section tended to talk with each other in a group after class. These groups were the ones that were formed by the instructor for purposes of doing the homework and were an obvious result of the instructors efforts. It was not clear, however, whether students in those groups pursued these relationships beyond the homework or classroom situations. There was little social interaction observed among students in the lecture-only sections.

Interpretation of cooperative problem solving data. When students in the cooperative homework group engaged in problem solving activities, the process appeared to be divided into two parts: (1) development of the problem representation and (2) application of the correct algorithm to solving the problem. Each part appeared to have its own evaluation process. For the first part, students engaged in activities related to understanding and defining problems.

Students were observed and also interviewed multiple times during the course of the semester-long course. Excerpts below are used to illustrate the impact of the cooperative homework experience on students' attitudes and problem solving activities. According to the data (see Excerpt 1), they were working individually at first. They next tried to understand the homework problems by themselves using various sources other than the help of their team mates.

Excerpt 1 (Representation of problems)

(Students meet in a team and start working on the first problem in the assignment)

(Students are talking to each other on a topic unrelated to the problem)

(M2 (male 1) starts to make notes and M1 (male 2) looks at his notes)

(F (female) also looks carefully at her notes)

(All three students silently try to work through the problem in order to understand the objective of the problem)

M1 : The point of this problem is not ----.

M2 : Yeah. Probably, that is too easy.

(All students laughing)

M1 : Look at the notes!

M1 : Q over 4 ages Potential is gonna be---.

M2 : Outside of field, we can pretend that point charge---. Can we do that?

M2 : We can use two equations in here. One situation is when we have same values on the --- and the other condition is when we know the ----.

M1 : The point of interest here is surface of field.

M2 : Yeah. Not point of surfaces.

M1 : So?

M2 : I got an another idea. See what you are thinking. OK? All right.

We got two surfaces in here and we draw the charge on them.

When there would be like uniformly distributed to the surfaces of field.

M2 : No! it's gonna be proportional to the surface area.

M1 : Conductors. What happen to the surface?

M1 : We agree that both voltage are the same. So, that crosses out.

M2 : Can we use this ?

M2 : You know, we can calculate electric field between them assuming that we have charge of Q. And, then, once we do that, we can integrate the voltage that we know.

M1 : We don't know the charge density?

M2 : No! But, we know that is even.

Second, they exchanged their understandings on problems to see if their representation was right or not. If there was a disagreement in their understanding, they started working on the difference among their definitions and the objectives of the problem. They negotiated to resolve these differences based on the information from a variety of sources such as notebooks, text, prior knowledge, or knowledge from other courses. Then, they made one best scenario (representation) for the problem.

Breaking down the problem solving process into two parts, negotiating the meaning of a problem and actual problem solving, seemed to be an effective strategy for reducing students' cognitive load and for avoiding the risk of additional work. That is, it appears to have been more advantageous, in terms of solving the problem effectively, to do it this way rather than trying to first solve the problem and then exchange their respective solutions. First, this latter approach would not have been an effective means of group problem solving (Each week a group leader, appointed by the instructor, met with the instructor and the other group leaders to discuss group processes. So, the instructor kept tabs on how each group was functioning.). Second, if differences in opinion did occur, the students would then have to go back through the whole problem again in order to resolve their differences. In spite of what appeared, on the face of it, to be a time consuming process, negotiation seemed a more useful strategy for successful cooperative problem solving.

Second, compartmentalization has been found to be related to reduction of cognitive load and reducing cognitive load has been shown to be an advantage of cooperative learning (Pea, 1993). In addition, cognitive resources can be saved by dividing the problem solving process into naturally occurring pieces as happened in this study: The homework problems assigned in the course required extensive knowledge of other subjects including electronics, mathematics, and physics. Separation of the understanding and computational components can spare some of the burden on students' cognitive resources.

Excerpt 2 (Applying the algorithm and Monitoring)

F : What formula did you use?

M1 : Coulomb's law

M2 : Did you get for the charge

: What's the cosine pi?

M1 : One

M2 : OK.

F : Why did you put y equal zero ?

M2 : OK. You are right. It is not zero.

(M1 works on the fourth problem)

(Now, F starts to look at problem)

(M2 read the text and ask a question to M1 about the understanding of problem)

M2 : R prime is the vector from zero to whatever. That's why you are integrating over.

So, it just be any times R.

Where is R?

M2 : I think that R equals zero and R is constant.

That looks a little strange?

(M2 try to come up with explanations why he ends up with this algorithm)

M1 : Oh! This does perfectly make sense.

(M1 explain his understanding of the problem to M2) (Both agree on this answer)

For the second phase of the problem solving process, students engaged in applying formulas and computation. The data again show that students in a group first solved problems individually without talking to each other. Little of the initial conversations related to specific knowledge about the problem. They did not exchange their opinions before they first got their own answer. This may reflect the fact that they were expert novices rather than completely novice, in that they already had extensive knowledge in the subject. Therefore, they may have wanted to work on the problem by themselves, first, to see if they could find the solution. The observation data also showed that, at this same time, students were constantly checking and monitoring other's problem solving activities.

<u>**Interpretation of interview data.**</u> The interview data indicated students in the cooperative learning sections had a positive attitude toward cooperative learning. Students' comments suggested that they felt the cooperative learning method was better in terms of understanding materials and motivating their learning. Students in both the cooperative and lecture-only sections indicated that the instructor in the cooperative learning was more energetic and more active in his delivery of materials.

One student (student A) indicated he had had no experiences with cooperative learning methods. After he is transferred to the present university, he said that it was hard to get acquainted with other students because classroom sizes were so large and he was unable to meet many students. He specifically stated, however, that group learning was helpful in his getting to know other students and at the same time being able to do course work.

A second student (student B) started his freshman year at the present university and did have a couple of prior experiences with cooperative learning. He had some positive and some negative feelings about cooperative learning from these previous courses. When it did not work well, he indicated that it was because it was hard to schedule the time to meet students in his group. In case of student B, one possible explanation for this problem might be the lack of individual accountability. The importance of group goals and individual accountability is in providing students with an incentive to help each other and to encourage each other to put forth maximum efforts (Slavin, 1996). In any event, both students demonstrated a positive attitude toward cooperative learning methods by saying that if other courses were planned to be taught by cooperative learning methods, they would be willing and interested in taking them.

Finally, the interview data indicated that students in a group believed they understood problems better when they worked in a group.

Excerpt 3 (Advantages of cooperative learning)

Interviewer : What are the other advantages of group learning?

Student A : Sometimes a problem is just matter of ... you just do not know how to start problem. It helps to ... somebody can figure out how to start. And, ... um, if we are working alone, you just don't know where to start it.

Interviewer : So, you are saying that understanding a problem part is the best advantage of cooperative learning compared to other advantages. Is that right?

Student A : Yes. I think so. Understanding problems are probably the best advantages of cooperative learning.

This excerpt illustrates students' feelings about the benefits of cooperative learning and is in agreement with the results of the attitude surveys. The representation of problems is the one of the most crucial parts of solving problems. It appears that the cooperative learning technique is effective, when the each student in a group has a variety of resources of information (particularly knowledge related to the problem). The benefit is multiplied if each student brings this added knowledge. This is an important insight regarding instructional processes which permit students to share their knowledge with their peers.

In Excerpt 4, Student B received little help from the other students in previous groups in which he was a member. One point B mentioned was that he felt he knew the material better than his fellow students in his group.

Excerpt 4 (Problems of ability grouping)

Interviewer : What about understanding problems (through collaboration) ?

Student B : They help little bit?

Interviewer : Do you think that a bigger gap in terms of ability causes a problem in group learning?

Student B : Yeah. It does. That's more like a tutoring situation.

Interviewer : Then, do you think that ability level should be considered in cooperative learning?

Student B : Yeah.

This excerpt with Student B matches the observational data. Student B, who felt he had more skills and knowledge than his peers, dominated his group. He repeatedly led the discussion in group meetings. This inequality in interactions among students is known to threaten the building of a team-culture (Cohen, 1994; Cohen & Lotan, 1995). In such cases, low ability students may have a lower probability of interacting with other students compared to high ability students because of their relative lack of outside resources and knowledge (Cohen, 1994; Cohen & Lotan, 1995). In summary, a high ability student, e.g. Student B, did not benefit as much from cooperative learning in terms of understanding problems, but understanding problems is a major advantages of cooperative learning for low ability students, e.g., Student A.

<u>**Excerpt 5 (Monitoring problems)**</u>

Interviewer : What do you think about the idea of group learning in this class. Do you think that group learning is appropriate method for engineering courses like this?

Student A : I do a lot. First of all, because the material is difficult, I think it helps to have a group so that I can ask a question, when I have a problem.

You know, working on these problems, there is at least one person in the group who can get them all right, because there are so many ways of making mistakes and it takes more people to see those mistakes.

Interviewer : Yeah. I think that other students can check your mistakes.

Student A : Right. I make a mistake and they will find it. They make a mistake and I will find it. We find each other's mistakes.

Interviewer : What other advantages might you think of?

Student B : Oh. Sometimes, they point out like sign errors stuff like--.

Interviewer : Such as sign?

Student B : Yeah. sign errors. Sometimes they talk about concepts of problems, but-.

Interviewer : You mean error checking?

Student B : Yeah.

Both Students A and B pointed out that cooperative learning was helpful for checking their errors and mistakes. Students can continuously monitor their own problem solving activities in two ways, by themselves and with other students in the group.

The interview data for Student B raises some interesting issues such as memory for facts (see Excerpt 6). Student B reported that cooperative learning did help in recalling some factual information. Hinsz and others (1997) suggest that groups are superior to individuals on various types of memory tasks.

Excerpt 6 (Attitude toward cooperative learning)

Interviewer : Do you think that cooperative learning methods are appropriate for other engineering courses?

Student B : Yeah.

Interviewer : Why do you think so?

Student B : Well, sometimes you can't just recall answers and other students may give helps. It is nice to know that all the burdens are not always on your shoulder, if someone helps you.

Student A pointed out that students need to acquire cooperative learning skills because nature of expertise in engineering reflects cooperative work.

<u>**Excerpt 7 (Views on the field of Engineering)**</u>

Student A : Yeah. Also, you know, once we get a job, jobs in engineering are group working.

Interviewer : Could you say again?

Student A : When engineers after they graduate and they start to working and a lot of engineering departments work as a team.

Interviewer : In general, do you think cooperative learning is a helpful learning method for you?

Student B : Yeah. I do think it is worth it to put in my time. You are going to be working in groups sometimes. Things are gonna be changing so that if you get through a bad group, a better group will wait for you.

Student B provided more practical reasons somewhat related to Student A's response. The interview suggested that acquiring cooperative learning skills is important because other courses in engineering and subsequent employment may use cooperative methods. These two opinions might be related to each other, because some higher level engineering undergraduate courses in this university are utilizing various collaborative methods. It seems that students who are preparing for a professional career realize the importance of acquiring cooperative learning skills.

The interview data show that students did have a positive attitude toward cooperative learning, even though the degree to which they felt benefited from cooperative learning differed depending on their own abilities. Both cognitive and motivational aspects were identified as benefits of cooperative learning.

<u>Implications from the data</u>. Observational and interview data highlight important points about the nature of problem solving activities. Students construct a better problem representation in a group in part because of the increased amount of information and knowledge available. They also try to persuade or negotiate with other students in the group to come up with agreement on their problem understanding. Solving complex problems also often is accompanied by errors, some large, some small. Errors are usually due either to limited knowledge base or to lack of attention (Reason, 1990). The group learning data supports the fact that students made many mistakes during the problem solving process, but their subsequent homework did not contain these errors due, in part, to the checking by other students in the group.

Of the three roles outlined by the instructor for each group, the recorder role was the most easily identified. In one group, a female student who routinely wrote down problem solutions played a role of recorder. However, it was sometimes difficult to discern who was the checker or the coordinator. One reason may be the lower accountability of these two roles (Slavin, 1991a) or perhaps these roles are less obvious to students. The lower level of accountability may be one reason that students who have a great deal of knowledge end up dominating the problem solving process. Data showed that most of the times students who did not understand the problems tended to just listen or follow suggestions of the dominant figure.

Discussion

Results of this study are interesting in that they are in general agreement with previous research on cooperative learning. One caveat, however, is that students were allowed to volunteer for the experimental cooperative learning section. In other words, since there was lack of control, non-experimental factors are present in the data. As qualitative data indicated that there are slight differences regarding teaching style, there were a baseline differences among three sections. This might suggest that there was a lack of controlling nuisance variables in the study. This problem of non-equivalent groups was seen in the course satisfaction factor on the posttest, which may represent the effects of non-experimental factors. Since the course satisfaction was significantly differ among three sections, there might be a possibility that factors other than the experimental factor are involved in the experiment.

However, we do not know whether this is the case in this study. That is, there is also a possibility that high marks on course satisfaction in the cooperative condition compared to lecture only sections is an inherent effect of cooperative learning. Another issue is that students in the control conditions also formed study groups, but without the structure that was imposed in the cooperative learning groups. Such voluntary study groups are common in college level education (Slavin, 1996).

The analysis of both qualitative and quantitative data suggested that students in the cooperative learning section showed a more positive attitude toward cooperative learning than lecture-only sections. However, the differences cannot be attributed with certainty to the effects of cooperative, learning due to the baseline differences and non-experimental design. Students in the cooperative learning section had significantly more interactions with those in their group than did students in the lecture-only section. Cohen (1994) and Slavin (1996) have noted the importance of fairness in work load and evaluation of student work for the success of cooperative learning. Current research findings suggest that fairness was a concern for students in the cooperative learning condition in this study.

Cooperative learning did appear to improve opportunity for explanation of one's idea to the others and also for benefiting from others' explanations as well. This, in turn, improved understanding of the course materials. No differences between cooperative and lecture-only sections was found in time spent on course work, however. One issue that should be considered, in this regard, is the pattern of time usage. Given the on-task nature of the time spent in the cooperative homework groups, it might be the case that students in the cooperative groups spend the same amount of time but are more efficient in learning and in solving problems than their solitary peers. It is also possible, for example, that such on-task interactions were needed in order to ensure that the group could meet at times convenient for all the members and that, when these meetings were held, they were as efficient as possible (i.e., that all members had done their work prior to the meeting).

No increase was observed in social interactions among students in the lecture-only conditions (except for a very few voluntary study groups). More interactions occurred, however, among students in the cooperative learning section. This interaction appeared to spill over to those who were not members of their formal homework groups. In particular, inter-ethnic interactions appeared to increase in cooperative learning sections.

The group learning data showed that if there are inequalities in terms of ability in the group, the interaction patterns and types of assistance offered differs among the members. Students with higher ability get help from their peers in detecting any errors in computations or in misperception of course-related information, and students with low ability receive help in terms of problem understanding or problem representation. Exactly which among these students benefit the most was not clear from the current data.

The results from this study indicate some positive attitude change toward cooperative learning, even in spite of students' clear concerns regarding fairness of work and evaluation. The major benefits from cooperative learning that appear in this study are in agreement with previous research: improvement in understanding, more sharing expertise with peers, and redundant checking (monitoring) of group work.

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Appendix

Questionnaire for Measuring Attitude, Course Satisfaction, and Fairness Concern

Please circle the number on the right that most nearly describes your feeling on each of the following issues.

Circle 1 for Strongly Disagree, 3 for Agree, 5 for Strongly Agree

	Strongly Disagree		Neutral		Strongly Agree
1. I prefer to work on my homework by myself.	1	2	3	4	5
2. I prefer to work on my homework informally with other students.	1	2	3	4	5
3. I prefer to work on my homework in teams with other students.	1	2	3	4	5
4. When students work together as a team on a homework assignment, some are likely to do more work than others.	1	2	3	4	5
5. Working with other students helps me get a higher grade.	1	2	3	4	5
6. It is fair for students working together on a homework assignment to get the same grade on that assignment.	1	2	3	4	5
7. The professor's method of grading homework in this course rewards working with others.	1	2	3	4	5
8. I feel my previous coursework adequately prepared me to begin learning in this course.	1	2	3	4	5
9. I feel that I have been given enough information to be able to complete each homework assignment.	1	2	3	4	5
10. Working on homework in this course has helped me understand the material better.	1	2	3	4	5

	Strongly Disagree		Neutral		Strongly Agree
11. It would be helpful if team-based projects were used in other courses.	1	2	3	4	5
12. The amount of work required for this course is about right.	1	2	3	4	5
13. When compared to other courses I've had here at this university, the homework assignments are more helpful in this course for understanding the material.	1	2	3	4	5
14. I am comfortable working with the homework problems in this course.	1	2	3	4	5
15. I feel this course has helped me learn to solve engineering problems on my own.	1	2	3	4	5
16. I understand an assignment better when I work on it with others.	1	2	3	4	5
17. Working with other students on engineering problems helps me learn to listen to others' views about the assignment.	1	2	3	4	5
18. Working on engineering problems with other students helps me learn to explain to others how I arrived at a solution.	1	2	3	4	5
19. Explaining my solutions to others helps me understand the material better.	1	2	3	4	5
20. I like to work in teams with other students, especially to solve engineering problems.	1	2	3	4	5
21. Working with a team to solve homework problems is easier than working alone.	1	2	3	4	5

	Strongly Disagree		Neutral		Strongly Agree
22. Working in a team with other students to solve homework problems decreases the workload for each student.	1	2	3	4	5
23. The subject matter of this course is more interesting than I thought it would be.	1	2	3	4	5
24. If this course were not required, I would take it as an elective.	1	2	3	4	5
25. My experiences in this course have convinced me that I do want to become an engineer.	1	2	3	4	5
26. Based on my experiences in this course, I feel that engineers can work well together to solve engineering problems.	1	2	3	4	5
27. How useful do you find each of the following in helping you to understand and complete the work in this course?					
27-1. lectures	1	2	3	4	5
27-2. homework	1	2	3	4	5
27-3. assigned text	1	2	3	4	5
27-4. outside readings	1	2	3	4	5

28. How much time do you spend each week, outside of class, on work for this course? ____________

Table 1
Cumulative Grade Point Average

	Cooperative Section	Lecture only section I	Lecture only section II
1.5 - 2.0	1	0	0
2.1 - 2.5	0	1	4
2.6 - 3.0	5	7	3
3.1 - 3.5	6	15	9
3.6 - 4.0	6	13	6
Mean GPA and (SD)	3.09 (.92)	3.36 (.41)	2.93 (1.03)

Table 2
Items and Reliability for Attitude, Course satisfaction, Fairness Measure

Factor	Items	alpha
Attitude toward Cooperative Learning	1*(-.71), 2(.57), 3(.74), 5(.66), 16(.57), 17(.70), 18(.62), 19(.65), 20(.69), 21(.71), 26(.44)	.86
Course satisfaction	8(.47), 9(.66), 10(.73), 12(.66), 13(.60), 14(.78), 15(.58), 23(.72), 24(.45), 25(.52), 27-1(.57), 27-2(.68)	.83
Fairness Concern	4*(-.80), 6(.80), 7(.40)	.62

Note. * refers to reversed item
Numbers in the parenthesis are factor loading score.

Table 3
Attitude measure toward cooperative learning

ECE 220 sections	Attitude toward cooperative learning: Pretest M	SD	n	Posttest M	SD	n
Cooperative section (section1)	3.95	.47	19	4.16	.56	15
Lecture only section I (section 2)	3.65	.48	30	3.74	.59	23
Lecture only section II (section 3)	3.45	.55	20	3.61	.63	15

Table 4
Course satisfaction

ECE 220 sections	Course satisfaction: Pretest M	Pretest SD	Pretest n	Posttest M	Posttest SD	Posttest n
Cooperative section (section1)	3.70	.34	19	3.98	.37	14
Lecture only section I (section 2)	3.61	.39	28	3.69	.53	24
Lecture only section II (section 3)	3.41	.58	20	3.01	.49	15

Table 5
Fairness Concern

ECE 220 sections	Fairness Concern on Cooperative learning					
	Pretest			Posttest		
	M	SD	n	M	SD	n
Cooperative section (section1)	3.43	.59	18	3.38	.60	15
Lecture only section I (section 2)	2.55	.65	26	2.81	.42	24
Lecture only section II (section 3)	2.80	.56	20	2.98	.60	16

Table 6
Explanation

ECE 220 sections	Explanation					
	Pretest			Posttest		
	M	SD	n	M	SD	n
Cooperative section (section1)	4.32	.56	19	4.53	.55	15
Lecture only section I (section 2)	4.13	.58	34	4.19	.53	24
Lecture only section II (section 3)	4.05	.77	21	3.97	.69	15

Table 7
Understanding

ECE 220 sections	Understanding: Pretest M	SD	n	Posttest M	SD	n
Cooperative section (section1)	3.43	.59	18	3.38	.60	15
Lecture only section I (section 2)	2.55	.65	26	2.81	.42	24
Lecture only section II (section 3)	2.80	.56	20	2.98	.60	16

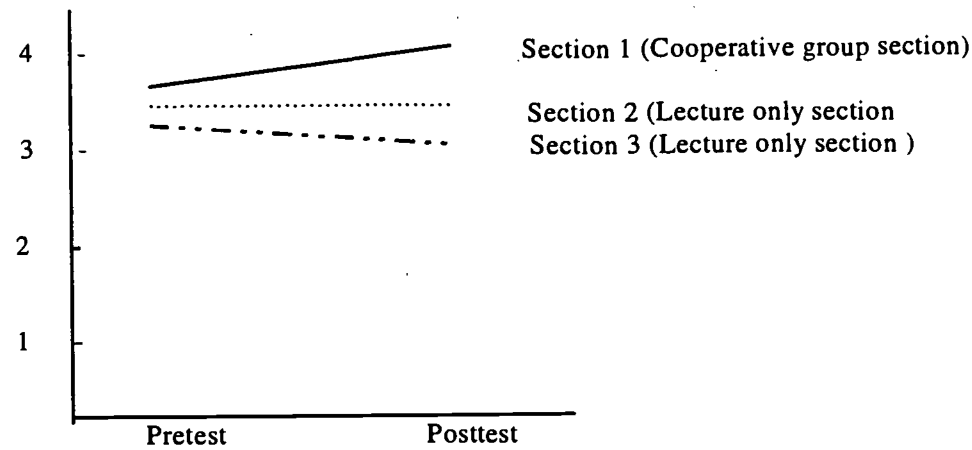

Figure1.Course satisfaction

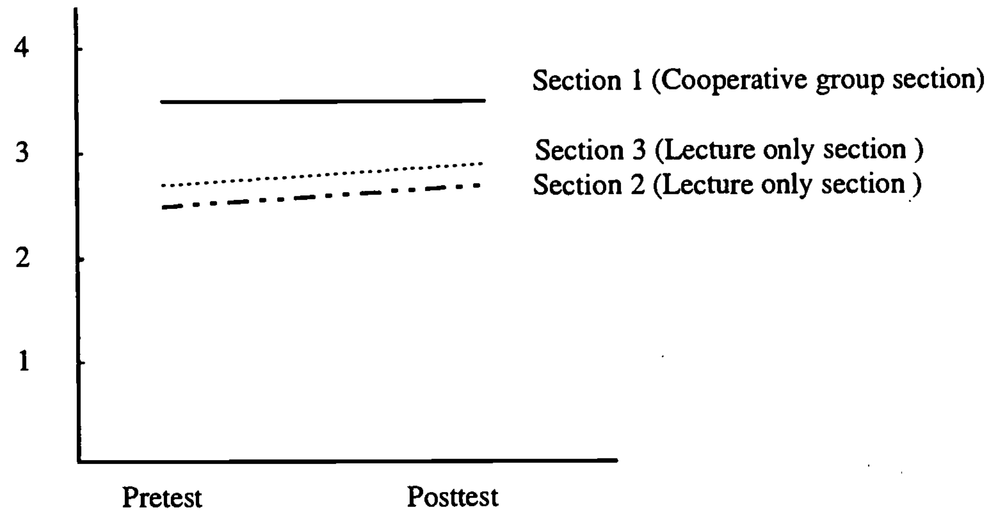

Figure2. Fairness Concern

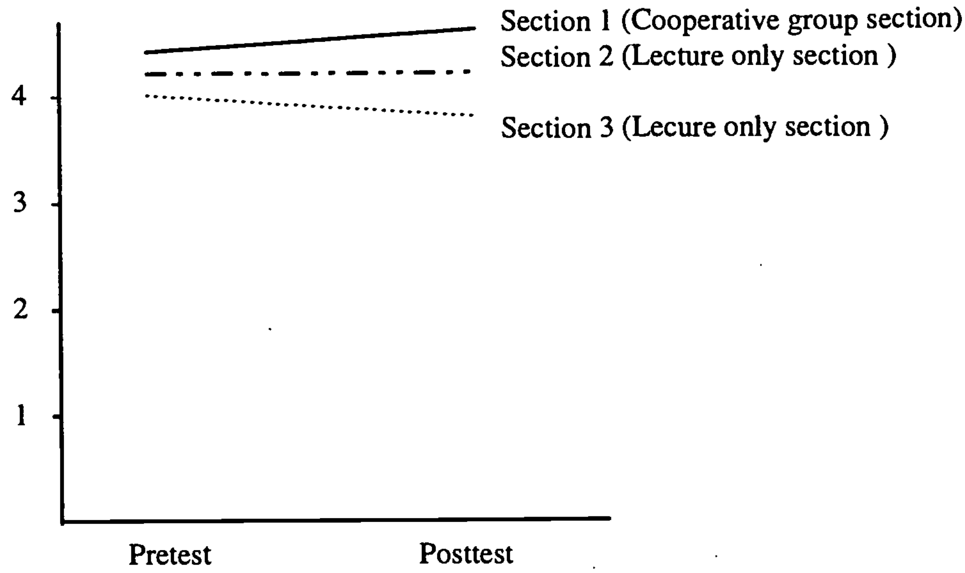

Figure 3. Explanation

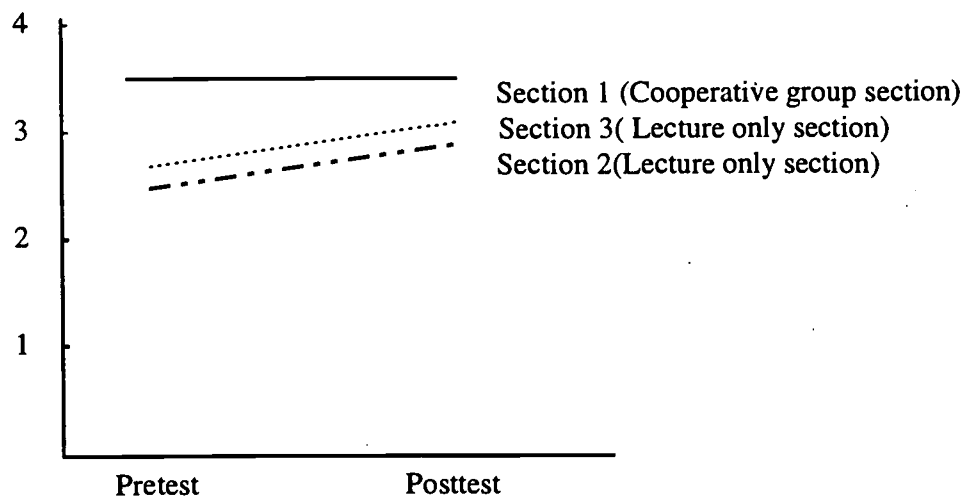

Figure 4. Understanding

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