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# Utilization of Active and Cooperative Learning in EE Courses: Three Classes and the Results

Karan Watson  
Texas A&M University

## Abstract:

*Educational researchers confirmed that active learning strategies will result in more retention of subject matter and a deeper comprehension of the concepts covered in a class. In part this is due to the fact that these strategies require that the learner assume more responsibility, during class, for the learning environment. In conjunction with active learning, much interest has been focused on cooperative learning strategies, which require that the students operate in a more cooperative, or team, mode versus the more traditional competitive modes. In this paper three Electrical Engineering courses at Texas A&M University which incorporated various active and cooperative learning strategies are presented. The information does not deepen the already present research on these strategies. However, it does present detailed examples of the assignments made which utilized active and cooperative learning, the adaptations in student grading procedures which were made, the attitudes of the students during the courses, and a brief follow-up on the students a year after the courses. The three courses described are: Introduction to Digital Logic, Introduction to Microprocessors, and Microcontroller Design.*

*For each course the course content, grading policies, and facilities will be described. The student evaluations of the course at the end of the semester, and the evaluation of the student's performance a year after completion of the course is presented. The findings from the utilization of the active and cooperative learning strategies indicate that whether these strategies are used exclusively in the course or to lesser degrees, they have a very positive impact on student attitudes, and on apparent interest in the field a year later. This study cannot claim to prove that the students perform better after the class, but a better attitude nearly always means positive performance results at some level.*

## Introduction

The advantages of utilizing active and cooperative learning techniques have been explored for students at virtually all education levels. To varying degrees these techniques have been found to be great tools for enhancing the depth of understanding, the breadth of topics which can be addressed, and the long term retention of the material by the students. David and Roger Johnson reviewed 369 studies from 1898-1989 where achievement was researched in competitive, cooperative and individual learning environments]. In a third of these studies there was no difference in student achievement when a competitive versus a cooperative environment was available. However, in the studies where there were differences found in the competitive versus the cooperative environment, 87% of the time the cooperative environment resulted in higher student achievement.

While faculty in engineering fields have been using many of these techniques for years, they are not utilizing the techniques in many areas or on a large scale. For example, engineering has long involved

laboratory experiences in conjunction with a lecture aspect of a course. This laboratory often provided a piece of the course which allowed students to get more actively involved in the learning process and often required some level of cooperative student efforts. Many engineering courses have involved design problems which are complex enough to fit well into a cooperative, or team endeavor. Finally certain faculty always seem to be able to develop a class atmosphere such that the students participate in much discussion and exploration in the class. Even though it is seen that some classes and some faculty have worked to have more active class participation and cooperative efforts on the part of the students, these approaches seem to be far outweighed by the number of faculty who simply lecture to the class and then evaluate students based upon individual performance on homework or examinations.

Often, faculty who have attended workshops to learn more about using active and cooperative learning techniques in their classes find themselves disappointed, due in no way to the workshop presenters, because the information they have received is not always easily or obviously translated into techniques they can use for their engineering courses. An illustration of this is that often in workshops on cooperative learning an exercise on survival planning in a harsh environment, (e.g., desert, Arctic, or moon survival) is a good way to demonstrate that a team working together on a complex problem, usually come up with better answers than an individual alone can. Many of my colleagues have said that they see this and believe it, but they are not sure exactly how to translate this type of effort into their classes. Therefore, in this paper I am trying to give more specific examples of techniques I have used in class. What I have observed is that none of these techniques or examples really surprised my colleagues. As a matter of fact many had occasionally used some of these ideas or styles for a variety of reasons in a class before. However, many of them had not really used the techniques throughout the course in order to really change the learning environment for the students. I hope that the examples given here help people who have not yet seen how to map the information on active and cooperative learning into their courses. Following brief definitions of active and cooperative learning, 3 electrical engineering (E.E.) courses which used the techniques are described.

## **Definitions of Active and Cooperative Learning**

In this paper we are using the term active learning to describe a classroom environment where the learner plays an active role in how the information is presented and processed in the class. Thus, a completely passive class would be one where the instructor delivered lectures and the students merely took notes throughout the class time. Even though the student may have to then become active in doing their homework, or processing the lecture information, in our definition this would not constitute an active class. An active class would involve the students having to take an active role, in processing the course topics, as they are covered in class. Some of the formats this activity might take include almost any form of immediate feedback the student provides the instructor about the topic under consideration, discussions about the topic with other students during class, student provided summation of information about the topic, or student explanation of elements of the topic. Although these things may often occur spontaneously in a class, an active class would plan their use so that they enhance the understanding of the topic and so that virtually all students get involved actively.

The term cooperative learning is often a natural part of an active learning environment, because when the students all become more active, this unavoidably allows other students to get more information from fellow students than they would in a passive class. However, I am using the term cooperative learning to describe a planned approach in the class where students must work together in either delivering information on the topics to one another, or in deepening their understanding of a topic.

Cooperative learning means utilizing a positive interdependence relationship among students to enhance common goals for the class. "This context implies that merely dividing a class into teams and announcing that students should work together with their group mates ("You four do this ditto together") is not sufficient for, much less equivalent to cooperative learning." [2] In the delivery of instruction a common approach might be the jigsaw method [3]. Here, students belong to a team. Each team member learns an aspect of the topic under consideration, in a pattern so all aspects needing coverage have a team member assigned to it. Then it is the responsibility of each team member to teach the aspect they have learned to the rest of the team. Another example would be where, in order to deepen understanding of a topic, two or more students might be required to solve a complex problem which involves having to truly know how to apply the topic under consideration. In the definitions here, virtually all of our cooperative learning examples and techniques are also active learning techniques.

## Microcontroller Design Course

The 'Design with Microcontrollers' class is a senior level elective course offered by the E.E. department. The students successfully completing the class earn 3 semester hours of credit. The students in this class are predominantly E.E., computer engineers (CmpE), computer science (C.S.) majors, and occasionally bioengineers or mechanical engineers. A prerequisite for the course is that the students have already been introduced to microprocessors and assembly level programming. Typically this course is offered once a year, and the average enrollment is usually 15 students. In the semester discussed in this paper there were 18 students in the class. The students included 12 EE, 2 CmpE, and 4 CmpS students. In addition, 12 of the students were graduating seniors that semester.

The content of this course focuses on learning about Motorola and Intel microcontrollers (e.g., Motorola 68HC11 or the Intel 8096). A major component of the class involves designing an embedded microcontroller in a control application. These included projects which utilized A/D converters, timers, and data links as well as the use of the microprocessor. The applications included such things as tracking systems, positioning systems, audio pitch tuning, or robotic systems. Each project had to incorporate a sensor or data collection device, an actuator (e.g. a motor, valve, pump, lights, etc.), and a display device (LCD display, CRT, or led banks), as well as a microcontroller development board. Therefore, the class covered topics on microcontrollers, sensors, actuators, and displays, as well as the application of control strategies.

The students were generally not hard to motivate to participate actively in the class, because they were professionally mature and many had Co-op or intern experiences; they self selected to take this course; and, they were generally self motivated toward a project of one sort or another (e.g. hobbies in music, remote control model vehicles, astronomy, and the like often influenced the project the students chose to be the focus of their design project). Traditionally the class involved 3 written exams (60%), a set of labs to introduce the student to the equipment (10%), a design project (working hardware and software 20% and report 10%). During the Fall of 1991 the grading format was generally the same, however the written exams were small group projects involving three students. Also instead of 10% of the grade depending on laboratory introduction exercises, each student was accountable for instructing the class on any technique or function they had mastered for their project, and all sensors, actuators and displays they mastered. The projects were still done by individuals, although it turned out that several students had systems which interfaced to other student's projects. Examples of what the class tests were like, and how the students instructed others follows.

For the tests the students were assigned into groups of three each. For the initial exam, the students were assigned so that majors were distributed among groups and so that each group had a wide distribution of student grade point averages. By the second exam, and especially the third exam, students' strengths and weaknesses on the course topics were more apparent. For example some students could do wonderful things with software, but not with hardware interfaces, and vice versa. Thus teams were assigned on the last two tests to try to assure that all teams had personnel whose talents enhanced the overall success of the team (in other words assign teams much as an industry with a product to develop would assign team participants). An example of a team test assignment was to design a system which used a keyboard, CRT, optic sensor, small dc motor, and the Motorola 68HC11 microcontroller board to control, monitor, and report on the rotation speed of the motor. Desired speed was to be input by the keyboard and the actual speed was to be reported on the CRT. The students were to address the expected response due to loading on the shaft. The format of the exam was such that on Monday team assignments were announced. On Wednesday the team project was distributed and equipment for the project was made available. On Friday the teams each had to report and demonstrate their complete design or a unique component of their design (in other words teams did not have to have a complete working demonstration). By the end of the day Friday students had to have a report on their complete design. Projects were graded such that all team members received the same grade with a maximum of 20 points possible. These points were distributed in the following manner: 1) how well the design met specifications resulted in up to 12 points; 2) the oral presentation of ideas could merit up to 3 points; 3) the written report could merit 3 points; 4) the perception that all team members participated and understood the complete design merited 1 point; and, 5) a final point would be awarded for a unique approach or component which exceeded minimal specifications (e.g., graphical display, exceptional control under varying loads, or a completely functional display.) On Wednesday when the test was distributed the students remained in the class or lab in order to fully plan their approach and work distribution for the test. On Friday each team had 10 minutes to present their solution. Class met in the lab so that a demonstration could be made if desired. The students had to schedule their time and work as a team to get so much accomplished in so little time. We related these constraints to unexpected deadlines that often occur in the profession, and that if the team was prepared the work could be done.

To encourage students to share information on microcontroller features they had mastered, on hardware or software techniques with which they had become proficient, or on a control strategy they were prepared to apply, they were told that no feature of their final project which had not been shared with the class would receive credit. After the sharing was modeled a few times in class this threat of grade deduction became a non-issue. Students were given a course plan showing on what day a topic would be covered, and they informed me on which of these topics they wished to introduce a concept. Thus, this was an ever changing list throughout the semester. On the day of the topic they wished to discuss, students presented in the order they signed up. Often there was no lecture at all on the topic because the students explained the material to each other. Sometimes the lecture revolved around a common dilemma for the topic or around a component they all seemed to have avoided. Lectures were rarely more than 20 minutes. Finally each day the students had up to 5 minutes to mention something new they had learned to utilize for the class or their project. This allowed students to help each other learn in an order they preferred instead of the class outlined order.

The students in this class became full participants. The scenario for them that was emphasized was that they must cease being students competing with each other, and must visualize themselves as a team, or a company, where the more expertise shared, the more success for the team. I am absolutely positive that we covered 100% more material, and the traditional material was more deeply understood by all of

the students in the class. The level and completeness of projects which the students demonstrated at the end of the semester were all as good as, or better than, the best projects seen in any prior semesters. It turned out that approximately 50% of the grades were As and 50% Bs; however, this is not an unusual distribution for such a senior level elective.

The students' evaluation of the class was exceptionally high. They rated the course content, delivery, and instructor as high as possible, without exception. There were criticisms of the course only in the area of some of the lab equipment and the textbook. When the class evaluations were compared against all other instructors teaching senior electives in the College of Engineering, this class was rated above the 99 percentile level (i.e., students rated it higher in all categories than 99% of all the other courses at this level). Many students responded that they felt better prepared both by the content of the class and the style of learning for their future industry positions.

The following year the EE students in the class were contacted. Of the 12 EE students, all had graduated. 4 were in graduate school and 8 were with industry. Four had jobs or research which directly utilized microcontrollers, and all claimed that the course had helped them secure these positions. The remaining 8 felt they would highly recommend the class, if taught in the same format, to all students in EE.

## **Introduction to Microprocessors**

The "Introduction to Microprocessors" class is another senior elective course offered by the EE department. Students successfully completing the class earn 4 semester hours of credit. This class is a prerequisite to the class described above on microcontrollers. The class has a prerequisite that the students must have completed a course in digital logic design. Although generally speaking it is predominantly taken by juniors and seniors in EE and CmpE, there is a broader spectrum of students from within EE who take this course than the microcontroller class described above. This course is offered every semester, including Summer, by the department in multiple sections. Each section (2 or 3 in the Fall and Spring and 1 in the Summer) range in enrollments from 35 to 60 students. This course had an enrollment of 45, with approximately 40 from EE and 5 from CmpE and CmpS.

In this course the students focus on the organization and structure of microprocessors, assembly level programming, and peripheral interfaces. Up to 25% of the course grade is determined by a set of prescribed laboratory experiences, which students conduct individually. In the laboratory the students exercise, with assembly programming, the capabilities of a Motorola 68000 and other peripherals found on an existing educational board. In addition the students have some laboratories requiring initial use of a logic analyzer. The remaining 75% of the class grade is determined by 2 tests and a final (60%), and homework grades (15%), all done by individuals working alone. In the Spring of 1991 this grading policy was not changed, except that it was emphasized that homework could be done in groups, but copying was considered to be unethical.

An example of an active and cooperative class exercise was in order to introduce the students to the assembly level instruction each student was assigned an instruction or 2 at the end of one class. They were to learn the functions and constraints of their instructions by the next class. During the next class each student had 1 minute to explain each of their instructions. The following day a function to be programmed was discussed and flow charted. Then the students, in a somewhat chaotic manner, were allowed to write the program in assembly, by only being allowed to write the instruction they were responsible for on the board. Small debates as to why 1 instruction may be more useful than another,

or why one ordering of instructions may be preferable, were conducted and resolved by the class. During the class 2 or 3 functions would be programmed, and when a new programming strategy was introduced we might develop a program this way once again. On these programming days, at the end of the period any student who had none of their instructions used that day briefly explained why they thought they were not a vital instruction for the functions programmed. On some of these days the students also wrote the program in machine language on the board. The students whose instructions were rarely used soon became a source for humor and compassion from the class, and the whole class often rejoiced with such a student when their instruction became useful.

In another use of cooperative learning, the students would be placed in teams of 4 to 6 members. A jigsaw technique was then used to introduce the students to the functions and control of a peripheral device. For example, a device such as a parallel/serial port interface with a timer might be the topic. Such a device with 5 data ports and one timer would be assigned 6 topics (port 1, port 2,..., timer). Each team would have 6 members, and each member would be assigned one of the 6 topics. If a team had too few members for the number of topics the instructor filled in for those slots. Then the teams would disperse and people would congregate according to the topic they were to learn. Typically 10 to 20 minutes would be spent by these groups of 7 to 8 participants who were striving to learn about their assigned feature. The instructor was available to answer questions. Finally, the teams were reassembled with at least 15 minutes available, so that they could instruct each other on what they had learned.

In this class assembly language programming was covered much more quickly, and most of the class time on this topic was spent actually developing programs. It appeared the majority of the class learned the organizational and functional techniques, in addition to instruction definitions, much more quickly and more permanently. It was also obvious from the tests that the students were much more capable of machine coding and determining the timing a program took to run. The class was also able to cover many more peripherals than the classes taught passively typically did. In addition more of the features of the peripherals were understood by the students. Finally, although attendance was not taken daily, it was observed that the student absences from class were much lower than in the passive class (which may be a significant feature as to why the students seemed further ahead by the end of the semester).

The student evaluations of the course were above average for this course and for this instructor in this course. Criticisms were levied on the text, the laboratory equipment, and the length of the individual tests. A few (3) students felt that the often chaotic nature of group activity during class was unsettling to them, even though they did learn during these periods. The vast majority of the class recommended that more active learning opportunities should be used. Many comments reflected that they learned more because they got the learning process more openly with classmates. Several said it was the first College course they had taken where they did not have a sense that they were pitted against their classmates. The grade distribution for the students was similar to other sections of the class, in that, about 20% of the grades were A's, 35% B's, 30% C's, 10 % D's, and 5% F's. The F's were earned by students who missed lab and class regularly. The D's were received mostly by students who did not complete labs, or failed to turn in homework.

The following year most of the students were still enrolled as undergraduates. Several of these students had enrolled in follow-up courses on microprocessors, microcontrollers, or computers. In addition, a large number of the students felt that they had or would use aspects learned in the class in their senior design capstone projects. All of the students contacted (about half of the class) felt that this class had given them an excellent understanding of microprocessors and better ideas about how to

learn.

## Introduction to Digital Logic

The “Introduction to Digital Logic” class is a required course for all sophomores in EE and CmpE, as well as any CmpS majors who are minoring in EE. The class is worth 4 hours of semester credit. This course is the prerequisite for the Microprocessor course as well as a computer architecture course. This course has a co-requisite which introduces circuit analysis and components. It is offered in 2 or 3 sections every Fall and Spring and 1 section in the Summer. The sections typically have 48 to 80 students enrolled, although the laboratory for the course involves groups of 16-20 students. This course was offered in a section which involved 64 students, all of whom were EE or CmpE majors.

In this course the students are introduced to Boolean Algebra, digital logic devices, and the analysis and design of digital combinational and sequential circuits. The lab requires the students design functions using TTL SSI and MSI components, as well as focuses on the use of programmable logic devices. The typical grading policy for the course is based on 3 tests (45%), homework (15%), a final exam (20%) and the lab (20%). All of these requirements typically were based solely on the individual’s performance. This course often has a bimodal grade distribution. An example might be that 30% may receive A’s, 10% B’s, 30% C’s, 20% D’s and 10% F’s. The lab almost always pulls the students homework and test average up. In the course offered in the Spring of 1993 the grades were determined as follows: 3 tests (45%) taken in class by individuals, 15% on problems done by teams of 4 during class, 20 % on 2 team projects, and 20% on the lab.

Therefore, one change in the class grading was that the individual homework assignments done out of class by individuals were replaced by 15 team problems done in class. These problems were similar in nature to homework problems, but usually more complex than many homework problems. For example, when the students were learning about Karnaugh Mapping techniques for logic minimization, the team would have to do a 6 variable reduction. The information on K-Maps would be presented on the first lecture day of the week, and all of the procedures would be explained. The next class day the students could ask questions on the use of the technique. Then a team assignment was distributed, and the team would have 20 minutes to turn in a written answer. Each day 4 teams (there were 16 teams) would be called upon to explain their answer to me. It was understood that I would randomly call upon any one of the 4 team members, therefore it was important that all 4 understand the answer derived. The team grade on the assignment was based on their discussion answers (if they were called upon) 50%, and the written answer 50%, or 100% dependent on the written answer. As the semester progressed the team assignments included more complex logic designs and timing analysis. Team member assignments were made randomly by the instructor, and there was a change in team members 4 times during the semester.

For the last 2 projects, which replaced the final, the students could pick their teammates, but they had to participate in 2 completely different teams. The first project called for them to design a controller panel for a CD music player, and the second called for them to design the logic for a 16 bit, 8 instruction computer. The report of their designs included information on the assumptions they made and the special features they had included. The schematics had to be completed using a CAD tool. Each team had to evaluate the performance of other team members on these projects.

All of the team assignments and tests in the course were returned to the students during the class period after they had turned them in. When material was returned the teams had a chance to discuss

the assignment and ask questions about their answers or reports. No new topics were introduced until students felt overall resolve about the current assignment.

I am certain that we covered more material in this class than was done in previous semesters when I instructed the course. In addition to covering more material, we seemed to have more understanding from a greater number of students for the material. I attribute this in a great part to a sense I have that the students, in large numbers, began to read assigned material in the text before coming to the class where the information was to be discussed. In previous semesters I had used pop-quizzes to try to encourage this, with some success. In this class the students were motivated, for the most part, by a desire to not let their teammates down. Some teams even met for a brief period of time before class to discuss the readings so that they had their questions answered before the team assignments were made. The attendance of classes was also significantly higher during this semester. The designs done by the students were very good for sophomore students, and seemed to pull the course together for almost all of the students. The grade distribution changed significantly in that it was not bimodal. There was a distribution of 31% A's, 39% B's, 20% C's, 7% D's and 3% F's.

The overall student evaluation of the course was slightly higher than average for this instructor. Many of the comments revealed that students were not always comfortable with the teams and how they worked, but they felt overall that the team approach was good. Many students stated that they felt by getting assignments returned so quickly, the grades had more meaning in that they got the feedback they needed in time to make corrections in their thinking and understanding before the next assignment was required. The students rated the textbook higher than any evaluation had previously done, and I attribute this to the observation that most were not waiting until the night before a test to read the text.

A year later, virtually all of these students are still enrolled in school, and most have chosen additional courses in the digital area. It is too early to tell if there is a significant change in interest, nor would it be possible to tell if this course caused the difference. The students who have taken follow-up courses in the digital area have performed very well in the following courses, however most of them were the top performers in the introductory course.

## **Conclusion**

I am convinced that more material can be covered, and the students will gain a deeper understanding of the material if active and cooperative techniques are used in all classes. This may be singularly due to the fact that the students become much more accountable for their own role as a learner, and because of their desire to not let their peers down. The techniques seemed to be most appreciated by the students in upper-level classes and older students in the lower level class. None the less, most students seemed to respond positively to the techniques. Finally, particularly for the lower-level class, I would spend more time working with them on team dynamics and strategies, to at least give them some tools for understanding and resolving frustrations in the teams.

In the U.S. we have an educational system which emphasizes either students working against each other or alone. The students we see in engineering programs are the students who have become fairly high achievers in this environment. In addition the facilities are usually set up for this approach. Therefore, changing to a more active and cooperative environment presents many barriers. Nonetheless, the benefits to creating more knowledgeable students, and better 'life-long learners' seem well worth the effort.



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*mort@etp.com*

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