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Utilization of Active Collaborative Learning in Three Electrical Engineering Courses

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Abstract

Educational research has shown that students learn and retain information better when the educational process includes active cooperative learning. As a result the face of the engineering classroom is changing to include more in-class and team activities allowing the students to take a more active role in their educational process. The use of teams not only enhances the students' learning, but also provides them with valuable training that they will use in their future occupations. The authors of this paper survey three engineering courses in which they have introduced various active cooperative learning activities. The three courses presented are: *Introduction to Engineering*, *Microcomputer Systems*, and *Automatic Controls*.

Each course is described including course objectives, syllabus, and grading policies. For each course examples are given of the assignments, in-class activities, laboratory assignments, and projects in which teams are used. The attitudes of the students during the course and student evaluations of the activities as well as the course are presented. The challenges and contrasts between using teams in a freshman course (*Introduction to Engineering*) and upper level courses are also discussed. Finally the instructors give an assessment and evaluation of the courses and specifically address the active collaborative activities.

Introduction

Industry has made it clear to engineering programs that they want graduates who not only have excellent technical skills, but these new engineers must also have teamwork, communication, negotiation, and conflict resolution skills. Productivity in industry is not just a function of how well an individual can solve a technical problem, but how an individual can work together in a group to accomplish a complex task. As a result engineering educators today are finding it necessary to teach students not only the technical fundamentals of engineering, but also a host of other skills to ensure success in the work place[1]. One method engineering instructors are using to teach students the skills they need for the work force is active collaborative or cooperative learning.

In an *active learning* classroom students take an active role in processing the course material. Students solve problems, answer questions, formulate questions of their own, discuss, explain, debate, or brainstorm during class. In a *collaborative learning* environment students and faculty work together to achieve the course learning objectives. In c*ooperative learning* students work in teams on problems and projects that assure both *positive interdependence* and *individual accountability*. Positive interdependence exists when students believe that they are linked with others in a way that one cannot succeed unless the other members of the group succeed. Individual accountability requires the teacher ensure that the performance of each individual student is assessed and the results given back to the group and the individual[2].

At various stages of a student's undergraduate career, she may experience group learning at different levels. This paper explores three different classes where the instructors have incorporated some form of cooperative learning. Active cooperative learning techniques have been incorporated into the electrical engineering curriculum at Virginia Commonwealth University at various stages of the student's undergraduate career. However, depending on what professor a student has for a particular course, she may not experience group learning until her senior year. This paper explores how cooperative learning methods have been used in classes at the freshman, junior, and senior levels in an attempt to ensure our students do gain some teaming experience.

Introduction to Engineering

The Introduction to Engineering (ENGR 101) is a required first year course. This course introduces basic concepts and principles of engineering and provides the foundation needed to pursue a career in an engineering profession. These basic concepts common to electrical, computer and mechanical engineering are motivated in the context of real applications. This course emphasizes the systematic approach to problem solving, both individually and as a team member. These goals are attained through analysis, construction, and testing of an electromechanical system that incorporates elements from a broad range of engineering areas. The study of this system illustrates how complex systems may be decomposed into simpler modules. Laboratory exercises reinforce the concepts introduced in lectures, and classroom and homework assignments provide an opportunity to develop problem-solving skills.

Upon successful completion of this course, the student is able to: 1) decompose a complex system into simpler modules, and think logically about problems and the process of obtaining solutions, 2) apply basic circuit laws to analyze simple circuits, 3) use behavioral models of semiconductor devices such as diodes and transistors in circuit analysis, 4) understand the workings of various transducers such as speakers and motors, 5) build Karnaugh maps and develop Boolean expressions, 6) implement Boolean expressions using logic gates such as AND, OR, NAND, and NOR, 7) appreciate the practicalities of getting things to work and realize that actual products / systems behave differently from what is predicted by theory.

One of the important components of this course is the laboratory, which consists of building, analyzing, testing, and debugging a series of subsystems that comprise a programmable robot. Teams consisting of two or three students complete all the laboratory exercises. Students are free to choose their own partner from their lecture section. Their choice is made during or prior to the first laboratory period and must be reported to the instructor. It is expected that all partners in a group will contribute equally to the completion of a laboratory exercise.

In order to promote an active learning environment in the classroom, in-class team activities were given to the students every two weeks. Examples of the activities include performing system decomposition, analyzing electrical circuits, performing function minimization, and completing timing diagrams. On the whole students were given assignments that would take approximately five to ten minutes to complete and paired into groups of two to four students. Sometimes the students were asked to complete the assignments at the board and other times in their seats. The goal of these assignments was to get the students actively involved in the learning process. Through out the course of the semester the students required frequent encouragement to ensure they were working together.

The first group assignment, given on the second day of class and used to teach the concept of system decomposition, consisted of breaking the class down into nine groups of four and assigning each group a different system to decompose. The teams were given ten minutes to complete the activity and then they were asked to report on their work. The instructor monitored each group's progress by rotating around to the different teams. By assigning this activity early in the semester, an active cooperative learning environment was established for the rest of the semester. The second and subsequent in class group activities consisted of similar challenges, based upon the learning objects for that day's lecture. Additional examples of group activities included solving for power, current, voltage, or resistance values using Ohm's or Joule's laws, setting up node voltage equations, filling in Karnaugh maps, and completing timing diagrams. All of the in class teams were assigned by the instructor.

The teams in the laboratory were self-selected within the first two weeks of class. Since ENGR 101 is typically taken by freshmen, many of the students did not know each other before taking this class, this made the team selection almost as random as if the instructor had made the assignment, i.e. old friends did not self select each other. Officially student teams had two or three members, however, as the semester progressed, some teams worked with each other to help each other achieve the laboratory goals resulting in a teaming effort of four to six students. The instructor noticed a sense of camaraderie develop within the class which significantly enhanced the learning environment and the team experience. By encouraging the students to work in teams, the students learned to utilize each other's skills to accomplish a common goal.

Final course grades were determined as follows: in-class quizzes and assignments 20%, homework 10%, laboratory 20%, exams 30%, final exam 20%. Students were encouraged to work on the homework in groups. All in-class assignments were completed in teams of two to four students. Approximately 35% of the student's final grade was based upon team activities. The laboratory was graded based on several factors: participation (20%), notebook (40%), quizzes (10%), and robot performance (30%). Of the original thirty-six students enrolled in ENGR 101 section 003 in the Fall of 2000 thirty-three completed the class. Of the students nine women enrolled and twenty-four men, 52% were non-white male, nine were freshmen, eighteen sophomores, five juniors, and one senior. On the last day of class the students completed an exit survey based on the BESTEAMS[3] model. The results of the survey are telling. On average, most of the students who completed the survey reported that they very rarely experienced team conflicts. This could be attributed to the fact that the teams were small and the team experience always monitored either by the instructor in class or teaching assistants in the laboratory. 46% of the students reported that their team working skills had improved, 46% reported that their teaming skills remained neutral and 8% reported that their team working skills did not improve since taking ENGR 101. 33% of the students reported that they were neutral about the product their team produced, 50% were very satisfied with their end product and 17% were dissatisfied with their final product. Given the ratings of Poor, Below Average, Average, Good, and Excellent, the students rated their finished products accordingly: Excellent (25%), Good (25%), Average (34%), Below Average (8%), and Poor (8%). 58% of the class reported that this was their first team project. The grade distribution was as follows: 5 A's, 23 B's, 4 C's, and 1 D. A student who consistently missed class and quizzes received the D.

Student evaluations of this course were excellent. By engaging the students in the classroom, the students were more attentive to the material being presented. In class monitoring of each team's progress in completing a task allowed the instructor to readily identify those students who were having trouble grasping the material.

Automatic Controls

Automatic Controls (EGRE 454) is a senior level multidisciplinary technical electrical with a laboratory component. This course covers the design and analysis of linear feedback systems. Emphasis is placed upon the student gaining mathematical modeling experience and performing sensitivity and stability analysis. Topics covered include an overview and brief history of feedback control, dynamic models, dynamic response, basic properties of feedback, root-locus and frequency response design methods.

In the Fall of 1999 seventeen students took the class. The students were required to perform the laboratory assignments / design projects in groups of two or more. The projects included a PID motor controller, a DC motor system, a ball on beam system, a thermal system, a HERO robot, a unit operations chemical process system, and a neural network controller. The students were allowed to pick the project on which they wanted to work and were teamed with the other students who picked the same topic. For the most part, the partnerships seemed to work fine. When some students learned with whom they were teamed, they requested a change in project, which was granted. These students have been together for four years and know with whom they work well. The teams were required to give a final oral and written project presentation.

In the Fall of 2000 twelve seniors were enrolled in EGRE 454. The laboratory/project component of the course was changed to four assignments that each student was required to complete by the end of the semester. These projects included a Lego Mindstorms project, a temperature control system, a PWM motor control system, and a DC motor control system. The students were randomly assigned to teams for each laboratory assignment.

Comparing the Fall 1999 and the Fall 2000 classes, there were more team conflicts when the teams were assigned. In some cases, when the teams were dysfunctional, the instructor allowed the students to complete the assignments individually. Dysfunctional behavior included: team members not showing up for team meetings, two friends excluding the third team member from project assignments, one team member assuming the majority of the project load, and personality and work ethic conflicts. When any of the dysfunctional behaviors were reported to the instructor, the instructor called a meeting with the members of the team. If the problem was still not remedied, the instructor gave the team members the option of completing the assignment on his or her own.

In order to promote an active learning environment in the classroom, in-class team activities were given to the students every two weeks. Students were given problems to solve and assigned to teams. In some cases the students then went to the board to solve the problem and then explained their solution to the rest of the class. Some active learning assignments required the students work individually on in-class problems. The instructor monitored the students' progress and as individuals completed the assignment, they then helped their classmates in completing the problem. On the whole students were given assignments that would take approximately ten to fifteen minutes to complete. The goals of these assignments were to get the students actively involved in the learning process to allow the instructor to judge the students' competency in a given area.

On the last day of class, in the Fall of 2000, the students completed an exit survey based on the BESTEAMS[3] model. The students were asked to judge the overall teaming experience with the different teams on the different projects. The surveys ranged from the teams experiencing conflicts never or rarely (8) to teams conflicts occasionally to very often (4). This could be attributed to the fact that the teams were always assigned randomly by the instructor. Most students reported that their team working skills had not improved since taking this course. The majority of the students (all except one) reported that they were satisfied with the product that they produced. Given the ratings of Poor, Below Average, Average, Good, and Excellent, the students rated their finished products accordingly: Excellent (3), Good (3), Average (5), and Abstain (1). Every student in the class had previous experience with teamwork; this is expected of all students by time they reach their senior year.

The grade distribution was as follows: 3 A's, 5 B's, 3 C's, and 1D's. The D was earned by the student who had received the most complaints about participating in the team projects. Student evaluations of this course were mixed. While some students enjoyed the in-class active collaborative teaming experience, most of them were frustrated with the team laboratory projects. On the whole the students appreciated the active cooperative assignments given during the lecture. They were less enthusiastic about the assigned teams for the laboratory exercises. Some of the student comments about teamwork and the instructor assigned teams were:

> "Teams are good, but everyone should have to do a write-up that way the instructor can tell if someone 'gets it'.",
>
> "…hard to work with someone whose best friend with an identical schedule is in the same class. (There were) no real conflicts because I was rarely consulted and ended up having to do one lab by myself.", and
>
> "I realize that I have to work in teams, but it is difficult working with others who don't have the same work ethic as me…. I would have rather chosen my teammates."

Microcomputer Systems

Microcomputer Systems (EGRE 364) is a 4-credit hour junior level core course that is typically taken during the fall semester of the junior year. Prerequisites for the course are Digital Logic

Design and a structured programming course based on C++. In the Fall of 2000, 42 students were initially enrolled in the class, however, 14 withdrew (receiving a grade of W for the semester) leaving 28 students. Of the remaining students, 13 were seniors and 15 were juniors.

In Microcomputer Systems, students learn about basic computer organization, instruction set architecture, assembly language programming, the design of various types of digital and analog interfaces, memory systems, and microprocessor system design. The course culminates in a significant design project. In the Fall 2000 semester, 15% of the course grade was determined by laboratory experiences designed to reinforce concepts that are covered in class. The labs included digital logic design with Mentor Graphics Tools, MIPS assembly language programming assignments using the SPIM simulator, and assignments involving the Atmel AVR 8-bit microcontroller using the STK200 Starter Kit. The remaining 85% of the grade was determined as follows: 3 exams (45%) and a final (20%), homework (done individually) and in-class (group) assignments (5%), and the design project (15%).

Homework assignments were lightly weighted because of the professor's previous experience with these kinds of assignments. In the past, students tended to work together and would then submit duplicate copies of their group work to be graded as their own individual work. In-class assignments were used as tools to encourage students to solve problems cooperatively while in the classroom, so that they could solve homework problems individually outside of the classroom. An example of an active collaborative classroom assignment follows. Students were asked to work in groups of 3 to generate a state machine that detected a specific binary pattern. After generating the state diagram, students were to implement the design using flip flops. Afterwards, student groups were asked to share their solutions with the class, while taking constructive criticism from their peers. Through this exercise, and others like it, it was discovered that some students were weak in the prerequisite coursework for Microcomputer Systems. It is speculated that these group exercises led to the high withdrawal rate for the class. One third of the class (14 students) elected to drop the course without receiving credit. Of these students, it was observed that most sat idly by while their classmates participated in the group problem solving exercises.

Laboratory assignments ranged from strictly software labs using the SPIM simulator to mostly hardware interfacing labs using the AVR microcontroller. During the first part of the semester, the laboratories were heavily software oriented. Students were given programming assignments based on the MIPS assembly language. These assignments were to be completed individually. A typical assignment is as follows: write a program that prompts the user to input a single hexadecimal digit (via the keyboard) and displays the corresponding binary value on the terminal. These programming assignments were done individually although students were allowed to discuss algorithms and problem solving techniques with their classmates. It was observed that students with stronger programming backgrounds performed better than those who lacked the prerequisite structured programming prerequisite. This could have contributed to students dropping the class early on as these assignments were given during the first half of the course.

During the second half of the semester students worked in self-selected teams comprised of three students each. The laboratory assignments were hardware oriented and were instrumental in teaching the students specific features of the Atmel AVR microcontroller and its peripherals for later use in the student design project. These laboratory assignments were essential in preparing students for requisite teamwork on their design projects. In addition, the assignments helped the students become more comfortable with the idea of working with fellow group members. Although group work was strongly encouraged on the laboratory assignments, it was not mandatory. Hence, a few students preferred to work separately on the lab assignments although they were a part of a 3 or 4 member design group. When asked why, these students said that they wanted to make sure that they learned the features of the microcontroller for themselves.

During the last three weeks of class, students worked exclusively on their design projects, which culminated in a semi-formal presentation to fellow students and selected faculty members. In the previous offering of the class (Spring 2000), the design project was to implement a fictitious RISC processor (the SRC processor) using the Mentor Graphics tools. For Fall 2000, students were asked to program an 8-bit microcontroller to control or interact with hardware. Students were given a choice of five projects which included a simple calculator, digital alarm clock, vending machine, security/alarm system, and an interactive game of choice. They were not constrained to these choices, however, as they were allowed to come up with ideas of their own. The only stipulation was that every group had to submit a proposal which then had to be approved by the instructor, mainly to ensure that the project was feasible. Also, students were told that their projects would be ranked against each other, with the most innovative and original "working" project receiving the highest grade. This was used to motivate students to choose interesting projects and to do a good job.

There were 6 project groups consisting of 3 to 4 students each. Two groups implemented a security system which used leds found on the microcontroller starter kit; one group implemented a digital alarm system which used 4 seven-segment displays and a buzzer; another group implemented a vending machine that used the leds found on the microcontroller kit; a group implemented a simplified version of the game Battleship; and lastly a group implemented the game of Pong that simulated paddle and ball movement.

The design project was graded based on several factors: correctness/completeness (30%), complexity/originality (20%), oral presentation (15%), and documentation (35%). Peer rating[4] was used in the grading of the design projects. The project grades ranged from 40 to 100. On the last day of class the students completed an exit survey based on the BESTEAMS[3] model. The results of the survey are telling. On average, most of the 25 students who completed the survey reported that they very rarely experienced team conflicts. This could be attributed to the fact that the teams were self-selected, and were composed of groups of friends who shared similar schedules. Most students reported that their team working skills had improved since taking Microcomputer Systems and that they were genuinely satisfied with the product that the team produced. Given the ratings of Poor, Below Average, Average, Good, and Excellent, the students rated their finished products accordingly: Excellent (6), Good (16), Average (1), Below Average (1), and Poor (1). Although this is a junior level course, over half of the class had never participated in any form of cooperative or active collaborative learning.

The grade distribution (of the 28 remaining students) was as follows: 14% of the grades were A's, 43% were B's, 18% were C's, 11% were D's, and 14% were F's. The D's were received by students who consistently performed poorly on exams and did not turn in all of their homework and lab assignments. The F's were mostly earned by students who failed to show up for class and lab on a regular basis. Additionally, the students who earned A's and B's typically did design projects that were more creative, i.e., the Pong game, digital alarm clock, and Battleship.

Student evaluations of this course were mixed. While some students loved the freedom given on the design project, others felt overwhelmed by it. Of the students who dropped the course, it was found that they were weaker programmers and did not quite meet the prerequisites.

Conclusion

It is our experience that freshmen are less willing to work in teams in the classroom. When presented with the opportunity to perform in class team activities, the freshmen were far less willing to team up than the seniors. Perhaps it is because they are less familiar with each other. The authors believe that by the time students reach their senior year, they are more familiar with group and teamwork. The senior-level students seem to be more comfortable and willing to work together for a common goal. This can be attributed to the fact that seniors have had classes together for four years and are more familiar with each other. It is also our experience that the upperclassmen are less willing to work in assigned groups. They prefer to select their team members themselves. The freshmen, however, are willing to work in either assigned or self-selected groups.

It has been shown that students benefit from cooperative learning activities in the classroom. It prepares them for the workforce and it also prepares students for graduate school. In both scenarios, students must be able to effectively communicate ideas to others and they must be able to problem solve effectively and efficiently.

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