

Experiments in Cooperative Learning: Successes of an Engineering Novice

Herbert Detloff

Department of Computer and Electronics Engineering

Peter Kiewit Institute of Information Science, Technology, and Engineering

University of Nebraska College of Engineering and Technology

Omaha, NE 68182

Abstract - *The results of two experiments performed over a period of four semesters demonstrate the benefits of active and cooperative classroom activities. The insights and methods provided by Project LEA/RN (Learning Enhancement Action/Resource Network) discussion groups at Iowa State University have demonstrably improved student learning in engineering classrooms. Reversing the typical roles of lecture and preparation by using preparation assignments as first exposure to course material increases student involvement with lectures and provides a means for assessing student interests and individual difficulties. The increased student preparation also raises innumerable questions for subject development; lectures become module-processing events. Other lessons learned include the value of incorporation of students with previous exposure as guides to the unfamiliar expectations of the process. The social context of cooperative learning was also improved with students less inhibited when asking questions of peers and faculty.*

Introduction

During the 1997-98 academic year, Drs. Doug Jacobson and James Davis conducted Project LEA/RN workshops at Iowa State University. These bi-monthly sessions facilitated by engineering professors, provided training and resources for faculty interested in improving student learning in their classrooms with active learning techniques. Of special interest was the effort to consider and dispel some of the myths surrounding cooperative learning in the technical disciplines. [1] Active learning in technical laboratory exercises has long been accepted as beneficial. While active collaboration is necessary in lab settings, cooperative learning is often seen as appropriate to course content more subjective than engineering. Cooperative learning demands personal interaction between students, with faculty monitoring of social context. The exercise of interactive skills is often left to the humanities and social sciences.

The technical disciplines are frequently seen as the mastery of a series of closed-end problems. Engineering students can become very intent on rote and single correct solutions without sufficient reflection and consideration of

their methods and alternatives. Traditionally this leads to a better grade but leaves creativity hidden. ABET EC2000 has effectively mandated that in the future engineering education must prepare students to function on multi-disciplinary teams with professional and ethical responsibility. [2] This mission is seen as essential to engineering practice and is best integrated into the social context of core discipline learning and not presented in an environment viewed as distinct and often superfluous by the engineering student.

This paper is an exploration of attempts to integrate cooperative learning into courses taught over a two-year period during and following participation in Project LEA/RN. These courses were held at the University of Nebraska-Lincoln during a major shift in emphasis from a practical technology program to a modern computer engineering curriculum on the Omaha campus.

Background: LEA/RN Revelations

A search for instructional techniques and improved teaching abilities initiated the author's enlistment in Project LEA/RN. From the very first meeting, the author realized that he was using primitive and limited instructional skills. Becoming a better teacher required the study of other disciplines including educational psychology.

The first revelation was that course content and instructional methods are secondary to what and how the students learn. The assumption that the instructor's primary mission was to "cover" all the material itemized by the department syllabus was producing discouraging results to traditional summative assessment. The students were expected to passively absorb methods from demonstrations of single solution procedures. The possibility of alternative methods was never considered or presented.

A second discovery was that not everyone learns in the same way. There was no cognitive awareness that other people's heads might be "wired" differently. If students were not successful, they simply weren't working hard enough. A series of perplexing examples of students, who were tenacious, curious, and creative, performed poorly in classes led by the author. Students who would become

excellent engineers could not demonstrate their skills at the perceived level of ability. An assimilation of different learning styles was needed.

With involvement in Project LEA/RN came awareness of the concepts of active and cooperative learning. Students who are actively constructing their cognitive processes through interaction with classmates retain more meaning in long term memory. When students cooperate in formal and informal groups, they become aware of their own processes through explanation to others. When students observe the methods of others, they become confident with their own knowledge construction. Cooperative success provides important social support for the stressful learning situations encountered with difficult material. [3] The LEA/RN discussion group made it obvious that a major portion of the time used for lectures was lost because of the passivity of the students. While students who are reflective were not given the time to process the information, students who are active learners got no opportunity to “do something.” Old methods would have to be revised to reflect these concepts of student centered learning. Instead of concentrating on the exposure of all the course material, a new focus on the students, collectively and individually would begin.

After being warned of the attending difficulties, revision began slowly. After the first semester with cooperative learning methods, the large increase in preparation and evaluation time required by the active techniques presented a severe temptation to return to lecturing exclusively. The decision to continue was the result of a realization that the instructor's *raison d'être* in the classroom is the student, not the subject matter.

Over the next four semesters, techniques were improved performing two separate experiments. The first was the sequential instruction of a single course to three different groups of students. This course had been offered twice without using active or cooperative learning techniques. This was seen as an opportunity to discover and analyze the advantages, problems, and responses to the methods. The second experiment was serving as the instructor for three different courses successively to largely the same group of students. This experiment studied the development of the social support systems and cooperative effort in a group with long term familiarity with each other, the instructor's expectations, and active/cooperative methods.

Experiment 1: Single Course Improvement.

The course is a junior level technology course (EET-3080) that studies commercially available digital logic devices. The primary emphasis is on the analog realities of digital integrated circuits and their interconnections. The focus has shifted in a new course (CEEN-3100) from commercially

available medium-scale integrated devices to CMOS VLSI design and interconnection requirements.

The general results of previous EET-3080 offerings were that all the material had been covered, but the students found tests very difficult and it was assumed that the assessment would be “curved.” The scaling of exam results reinforced this assumption. The rationale was that if all had done poorly, the instructor was at fault and should not hold the class responsible. The best students felt that what they demonstrated was acceptable as long as they were measured quantitatively better than the majority. The majority felt that as long as they were judged as competent as the rest they would pass the course. Competition, not learning, was being encouraged.

Semester 1: EET-3080 Digital Design and Interfacing

The experiment began by discussing with the class the concept of active involvement in the lecture. Some seemed initially confused, others thought it was some sort of game. The explanation that each student was responsible for the construction of individual knowledge was seen as a violation of the teacher-student contract. The demand of immediate involvement implied that the instructor was not completely responsible for teaching them what they needed to know. Questions such as “How will the in-class activity be graded?” and “Won't this waste class time?” made obvious the consumer orientation of their expectations. It was not easy to convince the class that there would be long-term learning benefits.

The first in-class activities were informal pairings of students to answer closed solution problems. Each student was asked to take two minutes to develop a strategy for solving the problem. The students were next to spend time explaining their method to a partner and listening to their partner's proposed solution strategy. Finally, each pair was to come to mutual agreement on a shared solution method. These initial exercises met with confused reactions of three basic types. The most common approach was individual effort to arrive at a complete solution. A significant number forged ahead and were frustrated by an inability to complete the work in the two-minute period. The emphasis on construction of a solution process was overlooked; the only measure of success was a quantitatively correct calculation. A second response was the complaint that a similar problem example had not been given. This reaction also implied that students did not understand the method step enumeration assignment or the possibility that there might be alternative procedures. A third result was only slightly more encouraging. A few of the better-prepared students enumerated their method and presented it to a confused partner. The pair proceeded to solve the problem using the dominant method with very little discussion of the method's merits. These partnerships considered the

exercise a success but few could explain their partner's contribution. It became obvious that rote replication of solution methods had been encouraged and only a minority had considered the development of understanding. Those that could focus on the process seemed to be uncomfortable explaining and sharing their skill. There would have to be metacognitive improvements.

During the remainder of this first semester, other active techniques were introduced. Informal pairings were used after 20-minute sessions to compare individual notes with collective editing and summations. A short quiz on information delivery preferences and a discussion of the general results made all aware of the differences in individual learning styles. [4] The students began to think about how they think. Group homework assignments were used to improve the level of discussion and reinforce the importance of individual and team process development vs. rote method replication. Teams were assigned for design projects. The students' interdependence improved individual skills of information organization and presentation.

Successful evidence of the active cooperative technique advantages was also present in individual exam scores. The average on the final was a full letter grade better than the two previous course offerings, but those students with higher abilities made the most significant improvements. The mid-level was expected to benefit from the added resources of their classmates' explanations but the performance of the best was a pleasant surprise. The exam problems that required insight, integration, and design had always been a disappointment. This time there were presentations of complete and creative solutions.

Semester 2: EET-3080 Digital Design and Interfacing

The second presentation of the course using active cooperative methodology was the final offering to technology students. The small size of the class offered a unique opportunity. The class was organized as a single study group. This improved the instructor-student familiarity and the course focused easily on individual learning. The small class size also presented some problems. The ability of the group members varied and cooperation was difficult to model. A significant amount of time was needed to establish procedures and expectations. Team interaction success is dependent on student observation of the alternatives presented by other teams. There are definite advantages to larger classes where students can use the organizational and conflict resolution ideas of other groups as models. The results of this offering are hard to generalize because of the class size. The author was however presented with the opportunity to experience the formal group interaction and cooperation from a perspective very similar to that of the students.

The familiarity with every student's ability and sources of confusion made it easy to encourage individual effort toward group task completion. The agreement made that the class would not move on until all understood the current material made for excellent interdependence and positive social interaction. When class members became impatient, reflection on the team methods presented positive suggestions. The instructor's leadership skills were taxed to the limit and the delegation of responsibility to group members was found difficult. This is the typical reaction of better students to the team assignment commitments. The author considers this portion of the experiment the greatest personal learning experience. The semester was completed with a clear vision of what had been asked of the students in the cooperative learning groups.

Semester 3: CEEN-3100 Digital Design and Interfacing

This was the initial offering of the digital design and interfacing course to students in the new engineering curriculum. Because of the changes to be made in course emphasis and the increased size of the class, major revision of the syllabus and class meeting procedures were demanded. With a larger class, some of the personal student-instructor familiarity would be lost. The rigorous content required that the schedule be maintained and attention to individual difficulties and interests was reduced. Decisions were made about what was to be discussed in class and what would be left to individual and group learning. An explicit enumeration of the course goals enabled all to focus on the course as an integrated whole. The course had specific procedures from the initial meeting.

The usual initial student negative reaction to cooperative learning was tempered by the inclusion of a few students with previous experience of group responsibility from the second experiment. At least one of these veterans was included in each formal study group. They were given the tasks of convincing their new team that this was not a game and helping relieve some of the concerns and shock of their teammates. Cooperative assignments were accepted quickly by a majority, reluctantly by a few.

Informal classroom activities presented new problems. The size of the class increased the amount of time necessary for the processing of pair and group results. In order to hold all accountable for their efforts it was necessary to spend time with as many groups as possible. At the beginning of the semester some avoided eye contact in order to avoid being called upon. As the semester progressed however, there were complaints about not being offered the opportunity to share. An equitable rotation was developed, but the usual vocal minority still occasionally protested. The amount of student preparation was

significantly improved from previous class offerings and some classroom periods were dominated by interesting insights, comparisons to previous topics, and questions that led to the next topic of study. Instead of struggling to keep the attention and interest of students, the lectures were guided by the class discussions. The students sometimes even seemed disappointed when the period ended. Only the most passive and shy needed to be prompted. The whole atmosphere of the author's class periods had been changed by three semesters of experimentation with active learning.

The traditional summative exam results improved dramatically. The average student result improved with no scaling adjustments, leading to doubts about the level of assessments. The average of the class was at the 'B' level. While it can be argued that the student attracted to an engineering program is clearly different from the average technology student, the author had never been considered a grade inflator. Students had clearly worked hard, demonstrated their abilities above expectations, and earned their grades.

Experiment 1: Results

Over the three semesters of this experiment, a conscious effort was made to keep assessment consistent. Homework assignments were replicated and the exam problems were kept at the same level of difficulty or duplicated. Some laboratory assignments were changed with the new engineering course to reflect the change in emphasis and the limited "hands-on" exposure of the typical engineering student at the junior level. Class sizes varied but the comparison of performance levels is considered direct evidence of the benefits of active classroom involvement and cooperative student efforts to focus on individual learning and group success.

Project LEA/RN provided the tools to change the author's instructional methods and the insights needed to understand students at new levels. By starting slowly with active and cooperative learning, building the in-class activity and assessment repertoire, and establishing explicit course goals, demonstrable improvements were made in student learning. This was done with no reduction in course content and no increase in class contact time.

The advantages of active and cooperative learning were presented slowly but consistently. Each of the course offerings however demanded that time be spent to familiarize the class with the techniques. Most students had never been exposed to an environment that demanded preparation, immediate involvement, and group maintenance. During the second semester of involvement in a Project LEA/RN discussion group an opportunity to study the construction of cooperative learning teams as an expected method presented itself.

Experiment 2: Social Context Development

These three courses are required on the Omaha campus of UN-L as part of the core curriculum for both electronic and computer engineering students. The courses are required in sequence and when asked to take CEEN-2130, a course the author had never taught, the opportunity to study the development of student expectations of active and cooperative learning was seized. This would be a long-term interaction with a group of students studying diverse course material. The introduction of cooperative activities increased preparation and assessment commitments. It would be easiest for an inexperienced instructor to revert to the typical lecture-exam format. The decision was made that active involvement of students would be an effective way to maintain interest during the three hour, once per week, evening format.

Of particular interest were the long-term effects on student professional social development. What would be the second semester effects? How would the expectation of a cooperative environment affect student learning in CEEN-3100 when the two experiments merged?

Semester 1: CEEN-2130 Electric Circuits I

The first course in the sequence required the usual initial training period. Discussions of the typical "World of Work" and "World of School" contrasts of team orientation vs. individual evaluation and simplex vs. duplex communication were used as justification of cooperative efforts. After twenty-minute lecture periods, the students were paired for activities. The first two meetings spent time processing both the actual assigned work and the students' mental state and memory following each short period. Students quickly became aware of their own attention spans and the potential of interactive problem solving. Team homework assignments were included after exercises in solution process construction and explanations to partners in informal pairings. The teams were explicitly instructed that one of the goals of the assignments was that everyone on the team must understand the solution process. All seemed to be going well until the difficulty of the material increased beyond the application of previous knowledge.

Textbook reading assignments are typically used as a preparation exercise for each class period. Instructors are usually aware that it is rarely accomplished. Students expect a lecture session as first exposure to new material. With only one meeting per week it became apparent that if all the most important course material was to be mastered, significant preparation effort must be expended not only on the instructor's part but by the students as well. There is an old saying, "What gets measured gets done." [5] The

preparation message was made clear. After explaining reasoning and justification to the class, homework assignments were made over material not yet covered. In order to complete the assignment each team would be required to investigate the textbook on its own. Class meetings were to be used for processing of the new information. This processing included clarification and verification of solution methods. Class time would also be used to explore other solution methods. The assignments would still be included in the final grade.

Both individual and group preparation increased. Students had prepared relevant questions and alternate solution methods. The class periods began to take on new life and lectures centered only on the most difficult topics. Students were willing to acknowledge that “We already know that.” and frequently asked to discuss the next topic. Using the study groups as preparation not only helped the weaker students but also encouraged the better students to consider alternative methods instead of replication of the textbook procedures.

Exam grades improved over the semester as the procedure of 1) group preparation, 2) classroom processing, 3) individual evaluation became familiar. Team assignments included integrative problems and design exercises. Some students were lost along the way, presumably because of their refusal to accept instructional methods that were unfamiliar, but in the end, those that remained enthusiastically looked forward to the next course.

Semester 2: CEEN-2140 Electric Circuits II

This was the author's first encounter with a group of students possessing prior experience and expectation of active and cooperative learning. Those without previous exposure were in the minority and quickly assimilated. The positive influence and acceptance of peers served as a valuable tool. Team building exercises and preparation assignments quickly returned to the demonstration level of the previous semester. Students were witnessed quoting some of the justifications for cooperative learning from the preceding semester to encourage the new members. The acceptance of the methods by student peers appeared to be the missing component to the initial “shocked” reaction to active exercises in the classroom.

First exposure to the course material via homework assignments was continued. As students became more confident with team identities and successes, class meetings were spent in assessing the learning that had taken place. After presenting the different solution techniques used, the majority of lecture time was used to introduce alternatives that provided further insight. The power of these alternatives could only be demonstrated with the prior knowledge attained through preparation. Instead of concentrating on the textbook method demonstration, we

began to use the knowledge constructed to explore other texts. Design projects were added to demonstrate individual and team abilities. Instead of limiting the amount of material to be “covered,” the active and cooperative techniques, and thorough student preparation, allowed the addition of “uncovered” topics.

Reflective review of classroom activities was facilitated by the appointment of one student to write the minutes of each meeting. Another student was appointed timekeeper. The timekeeper's job was to keep the session on track with a published agenda. These jobs were rotated according to a published and distributed schedule. Most students took these assignments seriously and a sense of activity ownership was established early in the semester.

When students expect to cooperate and actively collaborate with their peers, many new doors are opened. When students are truly prepared for class periods, the meeting time constraints no longer appear as limits to the amount of learning but as extensions to the process. Combining both cooperative learning expectation and preparation provided measurable increases in individual performance. With only one exception, each student with previous experience improved the final grade earned by at least a half letter grade. None of those without previous exposure to active and cooperative activities failed or dropped the course.

The lessons learned from this course offering were varied. First, use those with previous acceptance as guides for initiating those new to active cooperative learning. Second, emphasize preparation from the beginning, spending class and group time assessing it. Third, assigning individual organizational responsibilities enhances personal and collective awareness of classroom procedures. Lastly, be prepared for curious probing questions that take the class in new directions.

The social environment established in CEEN-2140 had become supportive. Most students were not only aware of the difficulties their teammates were having but concerned that all progress, willing to spend time and significant energy helping those that needed aid. When students needed help, most required little prompting to ask for it. After learning these lessons there was confidence that the two experiments would offer demonstrable learning improvements when they merged in CEEN-3100.

Semester 3: CEEN-3100 Digital Design and Interfacing

This semester was begun with high expectations of community. As discussed in Experiment 1, a larger number of students joined the group with extensive cooperative and active learning experience. These students had no expectations or history with the methods. From CEEN-2140, the power of peer influence on the initial class response had been learned. The “veterans” were to be used

as guides through the transition, extending the supportive elements of the previous semesters to a larger classroom and students with different learning styles. In order to use their experience, a single veteran was assigned to each learning team. The results of this experiment were mixed. While some helped with the assimilation task well, others became quickly discouraged.

The functioning of the preparation teams was distributed across a wide spectrum from exceptional cooperation and support to domination by individuals. The enthusiasm of veterans was reduced, and in some cases destroyed, by the minority of their views. The operation of a good learning team is not only dependent on experience but also personalities. By putting experienced students in positions of weakness, their effectiveness had been reduced. One-on-one with dominant personalities in their group, veterans found their methods and community disturbed. A supporting mechanism for leadership rotation was needed.

After spending some class time reviewing conflict resolution techniques and emphasizing that the group establish team as well as individual goals the results of preparation assignments improved. At the end of the semester, the unity of the class was finally established but several of the lessons learned had been qualified. First, when using those with previous acceptance, do not put them in a minority position. It would be better to have no one with experience on a team and have the evidence of other group successes as peer influence. Second, emphasize preparation and group skills, spending time in assessment. Third, assigning and rotating individual organizational responsibilities enhances awareness of classroom and group procedures. A comfortable and supportive learning atmosphere was eventually achieved and new lessons had been learned.

Experiment 2: Results

Active learning in a cooperative environment provides a powerful method for long term development of student social support and encouragement. When the methods become familiar and students view these techniques as normal, they begin to accept responsibility for their own learning. The initiation of the unfamiliar student still demands a major effort by an instructor, but the rewards upon acceptance are evident.

Conclusions

This paper has described the planning, performance and results of two experiments in active and cooperative learning. These studies were initiated in order to improve student learning in an engineering classroom. Personal experiences of the author have been included illustrating the

novice development of classroom techniques over a period of four semesters. The significant improvements made in teacher and student performance were the direct results of methods facilitated by Project LEA/RN at Iowa State University. These discussion groups provided the support and strategies. Drs. Jacobson and Davis provided the encouragement for experimentation.

Several lessons have been learned that have demonstratively improved the author's teaching efficacy. 1) The shift in the role of lecture from first exposure to learning processing enables the prepared student to "uncover" more course material. This is an immediate advantage when the exponential increase in undergraduate engineering information is considered. 2) Active cooperative exercises promote social support and encouragement for those struggling with difficult material. These exercises also introduce students to the communication skills needed on the modern engineering team. 3) A student-centered approach enhances the metacognitive skills of engineering students. When students are aware of the methods they use for problem solving and the contrast with those of others, new vistas of potential are revealed; creativity is valued over rote.

The most important lesson learned is that willingness to adapt to each student's individual learning style is essential for good engineering instruction. Cooperative and active classroom activities give excellent exposure to individual learning preferences that can be exploited in the teaching paradigm. This lesson alone has completely changed the way the author teaches and the level of student learning in his classrooms.

References:

- [1] Jacobson, D., Davis, J., and Licklider, B., "Ten myths of cooperative learning in engineering education," in *Proc. 28th Annu. ASEE/IEEE Conf.: Frontiers in Education*, D. Budny, Ed., Tempe, AZ, Nov. 4-7, 1998.
- [2] Accreditation Board for Engineering and Technology, *Engineering Criteria 2000: Criteria for Accrediting Engineering Programs*. New York: ABET, 1999.
- [3] Johnson, D.W., Johnson, R. T., and Smith, K. A. *Active Learning: Cooperation in the College Classroom*. Edina, Minnesota, Interaction Press, 1991.
- [4] Soloman, B. A., and Felder, R. M., *Index of Learning Styles (ILS)*, North Carolina State University,
- [5] Johnson, D.W., and Johnson, R. T., *Meaningful and Manageable Assessment through Cooperative Learning*. Edina, Minnesota, Interaction Press, 1996.