Active Learning in Large Lectures

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I. Introduction

Active learning is powerful teaching. I have used active learning techniques in undergraduate computer engineering courses at Iowa State University and Kansas State University. I firmly believe that the learner-centered, active learning exercises have enhanced student knowledge of the material. I was challenged by two large lecture courses during the 1997-1998 academic year. Each course had a class size approaching 100 students. Many instructors believe that a large lecture is not an appropriate active learning environment. I strongly disagree. Properly designed exercises with appropriate individual-accountability measurements work very well in large lectures. In each course, the students formed cohesive learning teams. The teams enjoyed the active learning challenge problems and directed class discussion. My role evolved from a lecturer to the role of facilitator and mentor. Facilitating these learner-centered classrooms is the most rewarding experience I have had as a faculty member.

However, managing large active learning classrooms is not for the weak-at-heart. Large lectures pose unique questions that must be faced when designing active learning environments. How will the large number of teams be selected? Is it possible to diversify teams in a large lecture when the student population is mostly homogenous? How can activities be completed in large lecture halls? What about the students that refuse to participate? Does active learning work for every student in the large course? Will the shear number of active learning teams foster competition, and is competition desired? What about incomplete teams caused by truancy? Is it possible to guarantee individual-accountability within the large student population? I had to find answers to all of these questions. This paper will discuss my experience designing and facilitating the active learning environments for the large lectures of my computer engineering courses.

II. Background

I began my teaching career in the Department of Electrical and Computer Engineering at Iowa State University. The computer engineering enrollment was increasing steadily while the computer engineering faculty size remained static. Thus, class size increased dramatically for the faculty members teaching core courses. I was the only instructor of one four credit-hour course on microprocessor systems design (CprE 301) from 1994 through 1998. My CprE 301 lectures met for 50 minutes three times per week and every student attended one three-hour laboratory during the week. The lecture grew from 40 students to nearly 100 students during these years.

In 1997, I was also gifted with a second large lecture to be taught each semester; a three credit-hour course entitled “Fundamentals of Computer Engineering (CprE 310).” CprE 310 had always been extremely unpopular because it was perceived by students to be a mathematics class. The real goal of the course was to introduce discrete mathematics within the context of computer engineering problems such as VLSI partitioning, information security, and job scheduling. Its unpopularity made it a difficult course to teach. Students attended lecture twice per week for 75 minutes. There was no laboratory component. This course also averaged nearly 100 students.

Thus, during academic year 1997-1998, I faced two large lectures each semester that had mostly homogenous populations of nearly 100 students. Two hundred students per semester definitely kept me exhausted most of the time. But, the two courses did provide an excellent test bed to study student learning and my teaching performance. I taught both classes as student-centered active learning environments. It was not an easy decision to completely defy the tradition of the blackboard lecture. It certainly was not easy to find the necessary time to create the active learning exercises. But, when the year was over, I was amazed at the quality of student knowledge, the quality of student interaction, and the quality of thinking and learning exhibited by students during the active segments of the lecture. How had I arrived at the decision to completely change my teaching methodologies? It happened because I had been willing to *learn about learning*.

I would like to believe that I have always been an effective teacher. My student evaluations had certainly boosted my ego, and CprE 301 was consistently ranked among the top courses listed by students. I have always attempted to make my lectures be *less* lecture and more high-paced student interaction in the form of question-answer and design problems. However, I realized that I was trained for this profession while I was a student. I sat in many lecture halls while the professor spoke to the blackboard and never once asked a student for an opinion, extrapolation, or related current event. In fact, I can think of only three professors that broke this mold during my ten years of university education. Also, I observed questions being disregarded and evaded by professors while I was a student. I think that is sad. I went to the university to have my mind challenged. Every student deserves that challenge. I strongly believe that this challenge comes in the form of student centered active participation. The university experience shouldn't be just about soaking up the words being enunciated or slurred by the person standing at the chalkboard. It should be about learning through doing. Besides, the research shows that student attention lags quickly in lectures where they do not participate[1]. With these thoughts in mind, I made the decision that I wanted to "undo" **any** passive lecture techniques that may have been embedded in my mind from my days watching professors. I joined Project LEA/RN™.

Project LEA/RN™ is a faculty development program at Iowa State University. Its purpose is to "enhance professors' knowledge and skills related to teaching and learning to increase student learning[2]." This is *learning about learning*. Faculty members participate from a variety of colleges within the university. Faculty members within the College of Education coordinate the activities. The focus is on active learning within university courses. A faculty member begins by attending an introductory workshop series, and can continue studying by joining a base group of faculty members. The base group meets to discuss and explore topics prepared by the Project LEA/RN™ staff or the group members. Much of the material discussed is drawn from an excellent text on active learning that provides a wealth of information and serves as a valuable source of references to explore[3]. After the first workshop, I was hooked on active learning. I took the material I was learning in Project LEA/RN™ and reengineered my course design. I vowed to never again have a classroom that was not student-centered.

I was not alone. Many of the faculty members in the department were also attending Project LEA/RN™. Slowly, we were effecting change within the curriculum. By fall 1998, at least four of the six core undergraduate courses were structured around active learning (CprE 211, 301, 310, 308). Two faculty members have been involved since the first Project LEA/RN™ workshop series. They have also published testaments of how Project LEA/RN has changed their view of education and their careers[4, 5]. In one of these papers, they mention myths commonly held by faculty members less receptive to the ideology of active learning. One of these myths is that active learning exercises cannot be done in large lectures. This is completely false. Active learning exercises can easily be done in large lectures without sacrificing the coverage of material if a professor is willing to carefully plan, organize, and facilitate the activity. This is well documented[3]. Cooperative learning research results are also well documented[3,6,7]. Faculty members often appreciate experiential reports from colleagues, however. This motivated me to write this paper. I will focus my remaining comments on how I implemented active learning in the large lectures of CprE 301 and CprE 310.

III. How I Implemented Active Learning in Large Lectures

Students began actively learning during the first lecture of the semester. This was the initial exposure for many students to an active lecture environment. Naturally, some of them resisted an environment in which their opinions mattered. Imagine that! Active learning played a large role in at least two of the three CprE 301 lectures each week, and in every CprE 310 lecture. I did my best to carefully plan each active learning exercise by analyzing:

- my purpose for asking the teams to complete the exercise,
- the type of thinking I wanted the students to explore,
- the focus of the exercise to the current course material,
- how each exercise facilitated student learning of the course goals,
- and how each student would be held individually accountable.

Often, I would discover that the first two bullets were easily answered while the remaining three bullets were the most challenging. In fact, I often abandoned an exercise I was planning because I discovered the focus (bullet three) was not sufficiently narrow to keep the students tasked toward learning the course material. Rather, the exercise would tend to naturally cause the teams to drift to other relevant and, worse, irrelevant topics. Each of the bullets is important, and I don’t feel that any bullet can be removed from the set. I do believe, however, that equally valid evaluations can be added to this set as instructors evolve their active learning exercise planning.

For me, the second and fourth bullets received the most thought. When analyzing bullet two, I knew that I did not want each exercise to have students thinking at the same cognitive level. I had been introduced to Bloom’s Taxonomy, so I attempted to spread the exercises over the levels of thought complexity[1]. During the fall of 1998, I have analyzed the questions and exercises I asked the students to complete during the last academic year. I discovered that even though I was trying hard to spread the questions across the taxonomy, my students were spending most of their time at two levels: analysis and synthesis. I didn't feel too bad after this discovery. After all, these two levels are quite high in complexity. However, I had unfairly limited student thinking by not effectively spreading the questions across the entire taxonomy. I have continued to study question and exercise creation as a participant in Engineering LEA/RN™ at Kansas State University. Engineering LEA/RN™ is a partnership between the Kansas State University College of Engineering and the Iowa State University Project LEA/RN™. The Engineering LEA/RN™ staff has provided participants with some excellent research reports on question writing[8]. After studying this material, I was well prepared to spread my active learning exercises across the entire taxonomy. My fall 1998 course included exercises that more evenly covered the entire taxonomy, although I still have a moderate bias toward the divergent analysis, synthesis, and evaluation questions.

When I analyzed bullet four for each activity, I had to guarantee that the activity cohesively fit into the learning objectives of the course. Davis and Jacobson point out that a common myth is that if cooperative learning is used less material will be covered[5]. They describe a process of reviewing a course to determine what is *really* the goal set. Like they, I also found a percentage of my course material could be removed without harming the course objectives. After removing this excess, I covered less material but I also had the time to facilitate quality active learning exercises. I believe that a carefully designed set of activities serves no purpose unless each activity adds quality to that cohesive fit. Accreditation processes require curricula to demonstrate the quality of the product they are producing. Thus, I spent a great deal of time exploring how the use of each active learning exercise bettered the quality of the student engineer. I guaranteed that every activity was closely tied to a learning objective, and then I rewrote the exercise again to make refinements that enhanced the learning objective. By recycling each activity in this manner before using it in the classroom, I hoped to have students exploring only the key concepts in a way that would guarantee a solid understanding. This detailed planning helped me avoid falling into an "exercise-without-purpose" trap.

Each active learning lecture followed a different timeline. I based my timelines on data that shows that student retention lags for a substantial period of time during lectures of varying length[1]. For CprE 301, I followed an activity timeline suggested by the Project LEA/RN™ staff:

Class Starts	12 minutes	30 minutes	45 minutes
Initial activity (2-3 minutes)	Longer Activity (7-10 minutes)	Closure/Initiate Activity (2-3 minutes)	Conclusion Activity (3-5 minutes)

Recall that CprE 301 was a 50-minute lecture. I created the 75-minute CprE 310 timeline based on the retention data[1].

Class Starts	15 minutes	40 minutes	55 minutes	70 minutes
Initial activity (2-3 minutes)	Longer Activity (7-10 minutes)	Closure/Initiate Activity (2-3 minutes)	Longer Activity (7-10 minutes)	Conclusion Activity (3-5 minutes)

I structured the activities using the style of the "informal cooperative learning environment" outlined in Johnson, Johnson, and Smith[3]. I used the initial activity to revisit a topic from the last lecture, or to introduce a new topic in an engaging way. I found that a short activity worked best because it required the students to focus on an activity in a meaningful way without straying far from the desired result. If the activity had been too long, the simple fact that they were still processing their pre-class conversations would have interfered with the learning goals. Many may argue that a short activity provides little time for them to truly develop the thinking needed. I disagree. My experience with this initial activity suggests that an activity focused on the lower Bloom's taxonomy levels of knowledge (define, list, and recall), comprehension (compare, explain, and summarize), and application (calculate, and demonstrate) works extremely well in shorter time periods. These levels require a type of convergent learning that students seem most comfortable with probably because they have been exposed to it throughout their educational career. Additionally, these levels require the withdrawal of facts from memory but do not ask the thinker to do much expansion on the stored facts. I must admit that my bias toward the analysis and synthesis levels of Bloom's taxonomy was sometimes reflected in the initial activities. I do not believe these levels were as successful in the shorter time periods because the students were not given appropriate time to synthesize solutions from their factual knowledge base.

I designed each longer activity to require the teams to interact at the divergent Bloom's taxonomy levels (analysis, synthesis, and evaluation). The seven to ten minute timeframe allowed the students to do quality work. A longer time period may have caused the teams to once again mentally wander from the learning objectives.

The closure/initiator activity was included to keep the students applying just-learned knowledge about a topic or to introduce a new topic. The halfway time was chosen because the retention data suggests that regardless of lecture length, students are not retaining or processing information well at the mid-point of a passive lecture. Students need to be rejuvenated with an activity.

The concluding activity provided the teams with the chance to process the entire lecture and prepare to study individually outside of lecture. It also focused their attention on the course material at a time when the tendency is to close the notebook, pack the backpack, and sit on the edge of the seat ready to charge out of the door.

The maximum time dedicated to active learning exercises was 20 minutes out of the available 50 minutes in CprE 301 and 30 minutes out of the available 75 minutes in CprE 310. I dedicated the remaining 60% of the available time to post-processing of the exercises with the students as well as standard lecture material. That's right! I don't advocate the complete removal of the lecture. In fact, lectures have both positive and negative attributes[3]. I use the lecture portion to distribute the factual information that the students need. I also use the lecture to work sample design problems that illustrate how I would approach the solution. These are both appropriate uses of the lecture.

Each active learning exercise was designed around the five key principles for successful cooperative learning: positive interdependence, face-to-face promotive interaction, individual accountability, social skills, and group process[3]. Each of these principles is easily achieved in the large lecture environment but engineering faculty members will probably find the instruction and reinforcement of social skills most challenging. The natural tendency seems to be to ignore how the groups perform socially. However, group social dynamics can directly lead to successful teams in industry and thus cannot be ignored by the engineering education community.

I will now provide an example exercise set from the second lecture in CprE 301. For each exercise, I will show bullets that demonstrate my reasoning during exercise planning and bullets that illustrate why I feel the exercise contains the five key principles for successful cooperative learning.

IV. Sample Exercise Set

Initial Activity: In the next minute, I want each of you to generate examples of everyday items that you believe contain a microprocessor or microcontroller as the control circuit. When I call the time, turn to your partner and share your examples. Listen to your partner's examples. Then, generate a new list consisting of ten examples that you both agree upon. Be prepared to share an item from your list and explain your reasoning with the whole class.

- **Purpose**: This activity will assess the prior knowledge of the students and allow them to explore the design space.
- **Cognitive level**: This activity has students thinking at the comprehension, application, and analysis levels of Bloom's taxonomy.
- **Proper focus**: The task is narrow and students should remain focused.
- **Goals**: This exercise targets one course objective (understanding how microprocessor systems affect human life) by exploring the application domains of microprocessors and microcontrollers.
- **Positive interdependence**: Students must generate individual lists and share them to generate team lists.
- **Promotive interaction**: Each partner must confer and use the other partner's knowledge base and personal experience.
- **Individual accountability**: The instructor will choose random students to share items from their team's list.
- **Social skills**: Listening, trust, and cooperative decision making skills are emphasized.
- **Group process**: The instructor will call on ten or twelve students from different groups at random to share an example and explain their team's reasoning. The instructor will ask appropriate questions.

Longer Activity: We have just finished discussing some of the architectural and organizational differences between microprocessors and microcontrollers. Join your partner. Imagine that you are engineers at NASA working on a new generation of Martian robotic rovers. One of you should spend the next five minutes writing a defense for choosing a microprocessor as the control circuit. The other partner should defend choosing a microcontroller as the control circuit. After five minutes, each of you should listen to your partner argue a position. Then, after listening to each other, decide which position you will take as a team. Be prepared to share which chip you have chosen and your justification with the class.

- **Purpose**: This activity has students process the architectural and organizational differences between microprocessors and microcontrollers, practice choosing an integrated circuit based on design constraints and specifications, and review the application domains of microprocessors and microcontrollers.
- **Cognitive level**: This activity has students thinking at the evaluative level of Bloom's taxonomy.
- **Proper focus**: The task focuses students on defending a single choice regarding the lecture topic.
- **Goals**: This activity reinforces the course objectives of understanding application domains, being able to compare and contrast microprocessors and microcontrollers, and being able to make design choices based on power, space, time, and cost criteria.
- **Positive interdependence**: Each partner must generate a defense and argue their position with their partner. The team must make a final design choice with documented reasoning in order to succeed.
- **Promotive interaction**: Each partner shares their arguments and thus their comprehension of the material just discussed in lecture. This promotes student-centered learning.
- **Individual accountability**: The instructor will choose random students during post-processing to share their team's design choice with the class.
- **Social skills**: Listening, respect for differing opinions, cooperative decision making, and arguing a case are all skills emphasized by this activity.
- **Group process**: The instructor will call on five or six random students to share their team's decision and reasoning. The instructor will ask appropriate questions.

Closure/Initiate Activity: Now that we have studied microprocessors, microcontrollers, their application domains, the major chip families, and some example integrated circuits from the major families, spend the next three minutes comparing your notes with the person sitting next to you. Together, mark the major points in your notes with an asterisk. Annotate and clarify your own notes if needed. Be prepared to share your major points with the class.

- **Purpose**: This activity will have students refocus on the major points covered so far in this lecture. The students are sent through the learning loop additional times by reading key points and possibly rewriting key points.
- **Cognitive level**: This activity has students thinking at the evaluation (assessing the quality of the notes and judging important points) level of Bloom's taxonomy.
- **Proper focus**: The task is narrowly defined and related to the important material of the lecture.
- **Goals**: This activity reinforces the learning objectives by taking students around the learning loop and asking them to judge important points.
- **Positive interdependence**: Each student must share notes with the other student and decide upon important points in order to succeed.
- **Promotive interaction**: Each partner shares their own understanding (annotated notes) of the course material. This provides student-centered learning.
- **Individual accountability**: The instructor will choose random students during post-processing to share their team's major points with the class.

- **Social skills**: Respect for another person's understanding and documentation of material, trust, and cooperative decision making are all skills emphasized by this activity.
- **Group process**: The instructor will call on random students to share major points until all of the major points have been highlighted.

Conclusion Activity: We've talked about a lot of material today. To bring it all into focus, I'd like you to work with two other students around you. Assign each student in the team the number 1, 2, or 3. Datasheets for three integrated circuits were at your seat when you arrived. Student number 1 will work with the Intel 8086 datasheet, student number 2 will work with the Motorola MC68000 datasheet, and student number 3 will work with the Motorola MC68332 datasheet. Each student should spend the first four minutes creating a summary that:

- provides architectural and organizational reasons why the chip is either a microprocessor or microcontroller,
- provides a sketch of the *basic microsystems model*,
- and provides a second sketch of the *basic microsystems model* showing the corresponding address, data, and control bus signals if the student's assigned chip were inserted as the coordinating integrated circuit.

Make three copies of this summary. Time will be called. Then, during the remaining three minutes, share your summaries with your team members and generate a hypothesis of why the chips are similar in so many ways. Be prepared to share your hypothesis with the class.

- **Purpose**: This activity assesses student learning of the lecture topics, forces students to revisit the key topics and go around the learning loop again, and keeps students actively discussing the lecture topics with each other as they prepare to transition to their next class.
- **Cognitive level**: This activity has students thinking at the synthesis, and possibly evaluative, level of Bloom's taxonomy.
- **Proper focus**: This jigsaw exercise keeps each student focused on synthesizing a system diagram for one microbrain and the team focused on synthesizing a single hypothesis.
- **Goals**: This activity reinforces the learning objective of comparing and contrasting differing microbrains and their system busses.
- **Positive interdependence**: Each student must finish his or her piece of the jigsaw puzzle so the team can generate a hypothesis.
- **Promotive interaction**: Each partner generates a written summary for teammates and verbally summarizes their individual work. The team members share their acquired knowledge and opinions in order to generate a hypothesis.
- **Individual accountability**: The instructor will choose random students during post-processing to share their team's generated hypothesis.
- **Social skills**: Trusting teammates to complete the jigsaw, listening, cooperative decision-making, respect, and patience are all skills emphasized by this activity.
- **Group process**: The instructor will call on random students to share their team's hypothesis.
- **Time**: This activity exceeds my typical five-minute conclusion exercise by two minutes.

V. Answers to the Questions

I mentioned in the introduction that every instructor facilitating active learning in large lectures faces many challenging questions. Some of these questions were listed. I will attempt to answer these questions by providing examples of how I approached a solution. I do not claim originality for my solutions, and in fact I imagine many of them are probably documented well in the research data.

How will the large number of teams be selected? I never allowed students to self-select their partners. I did not want close friends or study partners always working together. Rather I attempted to randomize the seating to increase diversity (see below) and then the partners were always "rooted at the left (or right) end of the row, create teams of two or three." I never used team sizes greater than three, because I really wanted the students to have a chance to work on promotive interaction and group skills. I felt that larger teams minimized each student's allotted participation time.

Is it possible to diversify teams in a mostly homogenous student base? Many schools have a homogenous engineering student base and thus this question naturally surfaces. In my active lectures, I was not implementing formal cooperative learning base groups that would meet outside of class. Rather, I opted for informal groups that existed for only one lecture. Thus, I couldn't efficiently use the high, medium, and low ability indicators (basically, G.P.A.s) for each student to diversify as suggested by Johnson, Johnson, and Smith[3]. Instead, I attempted to match the heterogeneity provided by the ability indicators by a simple pseudo-randomization of seating. I felt that the large number of students in the lecture made it likely that frequent seating changes could mimic teams that would be created by the ability indicators. Some of the techniques I used were:

- If your birthday is from January to June, start filling from the front of the room. If not, start filling from the back of the room… Now that you are seated, if your birthday is on an even day of the month, switch seats with someone in the same row whose birthday is odd, provided at least one student in the row has a birthday on an odd day.
- Left side moves to the right side. Right side moves to the left side. Now that you are seated, front moves to back, back moves to front maintaining your "side" of the room.
- Find a partner that is the same height as you and sit next to each other.
- Find your lab partner. You will never be partners in lecture. So, pick a partner for your lab partner that has the starting letter of the last name "far" from your partner's starting letter. For example, Barnes and Thompson have far starting letters.
- Find someone you don't know. Join them as a team.

Of course, this type of seating does take two or three minutes to do. I simply planned it into my lectures.

How can activities be completed in large lecture halls with fixed seating? Don't worry about it! These are bright, creative students --- they will make it work.

What about the students that refuse to participate? My straightforward answer is that they don't develop the same level of understanding as those participating, especially in the analysis and synthesis levels of Bloom's taxonomy. My aggravated answer is "lower their grade." The answers I use in my courses are:

- part of your grade will be calculated from your accountability during lecture exercises,
- during some group processing, your team members will be allowed to evaluate your contribution to the group solution,
- during most exercises, I will be evaluating the promotive interaction and social skills exhibited by the team members as I circle the room visiting with teams,
- you will be held individually accountable in lecture during group processing (I do mark my class list every time I call on a student so that I can guarantee every student is called at least once during the semester),
- and you will be held individually accountable for the material learned through the exercises by exam questions and laboratories.

These answers seem to convey the importance of the activities to the students without fostering an unsafe classroom environment.

What about the students that are truant? My answer to the last question holds here as well. Plus, the worse that can result during a two-person selection is one lonely student without a partner. Join that student to another group, and slightly modify the task of that group "on-the-fly" so that the added student contributes to positive interdependence and promotive interaction. By the way, if a class has an odd number of students, the same facilitation of a three-person group is required after creating teams of two.

Does active learning work for every student in the course? The answer, from my experience, is yes and no. Yes, every student benefits from circling the learning loop during lecture exercises. Yes, every student benefits from the peer instruction that goes on during good promotive interaction. Yes, every student benefits by learning the social skills needed to survive in a technically oriented group. Yes, retention increases because the normal down times during a passive lecture are eliminated; students are more actively thinking about the material throughout the lecture rather than just taking notes. And yes, average student grades increased in CprE 301 when compared against the grades of students from previous semesters when I had not used active learning exercises. Plus, I feel really good when my students finish the course with much higher critical thinking skills that when they had entered. With all of these yes answers, how does the no figure in? Well, after almost 400 students now, I have only had three students approach me in my office. One said, "I really think what you are doing is innovative and great, but I just can't learn this way." When I asked him why he replied, "Because I have been taught to fight for everything I want, and I'm not fighting to create the best solution myself." Another international female student replied to a similar query with, "Oh come on! I'm female and not from the U.S. They don't respect me because I'm different." On further questioning, I learned that her team members had never done anything to make her feel that way, she just assumed they didn't respect her because of past social and educational experiences. In all three cases, the students decided they could not learn actively without any evidence to back up their claims; all of their graded exams and assignments were average or above. Thus, students will *perceive* that they are not benefiting from active learning due to psychological reasons such as self-esteem, physical reasons such as stress, and social reasons such as diversity-issues and competition.

Helping the student eliminate this perception can be done in a number of ways. I reviewed recorded grades with the concerned students and pointed out their performance on key assignments. I also occasionally changed group selection methods by asking the students to partner with a friend in the class to lessen perceived hostility or indifference. I also added competition to more of the exercises. Active learning is not about completely removing competition through teaming. Teams can compete[3]. Some of the rewards I used were a best-solution citation on the course WWW page, a reduced homework assignment for the winning team members, and free pizza. Pizza is a vital food group for most students! Of course, using competition changes the way you facilitate group processing. Rather than random accountability, I would ask, "Which team believes that they have the best solution?" After they presented their solution, I would say, "Does any team want to challenge with a better solution?" Of course, the competition must be clearly announced in the problem statement.

Will the large number of learning teams foster competition, and is competition desired? In my experience, competition only occurs among teams if the activity is structured as a competition. Also, as mentioned in the answer to the previous question, competition can help many students really enjoy the active learning exercises. These students are those that have already been very successful in the traditional independent and competitive classroom. There are times and places for competition in the activities. After all, if we are preparing students for industry, they need to be prepared for competition.

Is it possible to guarantee individual accountability in the large lecture? Yes. As I mentioned earlier, I record every student that shares their team's solution with the class during the post-processing of an activity. I guarantee that every student is called at least once during the semester, but I kept the appearance of randomization by also calling on students that have already shared. Additionally, individual accountability for the material is tested on exams, quizzes, homework assignments, and laboratory exercises.

VI. Conclusion

This paper has documented my experiences learning about active learning and facilitating active learning lectures. Active learning ***is*** powerful teaching. Many engineering faculty members may believe active learning is powerful, but are afraid to implement it in their technical courses. Hopefully, this experiential report will help ease many of the fears that an engineering instructor may have about facilitating an active lecture. Additionally, I hope that the example activities that I provided illustrate how technical material can be mapped into activities.

My role as instructor changed in a number of very positive ways. First, I'm a better planner. I much more carefully examine course objectives and how I want the students to understand and apply the objectives. I also now plan activities for socially interacting humans rather than for passive information sponges that soak up my monologue. As a planner, I also read more about learning, teaching methodologies, and research results so that I can attempt to facilitate more effective activities. Secondly, my role became that of a mentor and facilitator rather than a lecturer. For forty percent of the lecture time, the students were abstracting, brainstorming, synthesizing, designing, judging, listing, specifying, and exploring. The students were learning from each other. The teams were practicing social skills that will make them successful for the entirety of their professional careers. Instructor designed activities were being used to peer explore and expand critical thinking. This ***is*** student-centered learning. All I did was walk around the room and provide insight if needed while evaluating student progress. I was mentoring apprentices that were learning from each other. Finally, I also became a trusted advisor that students felt comfortable approaching outside of lecture. Many of the problems the students wanted to discuss had absolutely nothing to do with lecture. My advice or referrals seemed to matter to them, however. I have always enjoyed this aspect of faculty life, and the increased number of students is encouraging since I believe it is directly related to the safe environment created in the active lecture.

Facilitating active lectures is hard work. I recommend that all instructors considering an active lecture do some serious soul-searching. It takes dedication and time. It changes priorities and focus. Other faculty members within the department may resist or be hostile because your instructional changes do not reflect well on those not willing to make performance improvements. People may scoff and state, "Why change something that has worked for hundreds of years?" Old paradigms *die hardly*; after all, that is why they are old. Don't take the skeptics' facts as facts. Do your own research. Learn about learning. Attend a faculty development workshop on active and cooperative learning. Network with other faculty members that have designed and experienced the active learning environment. Then, you will have a good factual basis to decide whether you wish to design active learning courses. For me, the rewarding feeling I get watching the success of a student-centered classroom is inspiring. I will never regret my decision to become a facilitator of student-centered active learning environments.

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