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# USING COOPERATIVE LEARNING TO ACTIVATE YOUR SIMULATION CLASSROOM

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## ABSTRACT

Active and cooperative learning methods represent a paradigm shift in the delivery of engineering education. These techniques recognize that the passive model of the typical college lecture does not work for many students. Instead, active and cooperative learning focuses on the premise that the students can learn best by doing and working with each other. Traditionally structured class periods imply that students listen to a professor lecture for about an hour. Cooperative learning can replace some of that lecture time with methods designed to get students actively involved during the class period. This paper presents the use of active and cooperative learning techniques applied to simulation education. Tips and examples for how to transform a standard lecture into a lecture based on cooperative exercises are given and the authors' experiences with these techniques are detailed.

## 1 INTRODUCTION

In the typical college classroom it is likely that professors are most actively engaged during the class time because they are walking about, expressing ideas in their own words, organizing, justifying, elaborating, and asking questions. The principles of *cooperative learning* are designed to get the student involved by transferring some of these activities to the student. Cooperative learning strategies are designed to motivate the students' interest and help their retention of key ideas by encouraging them to participate in discussions. In this model of teaching, the teacher serves as a facilitator and resource, the students interactively learn from each other, from the teacher, and from the process itself.

This paper presents background material on active and cooperative learning techniques and discusses why simulation educators may want to incorporate these techniques into the simulation educational experience. We highlight key techniques that allow students to work together in small groups throughout the class period to discover and explore the concepts for themselves.

Much of the literature on cooperative learning strategies and benefits focuses on non-engineering courses (see e.g., Brufee (1993), Sharan (1990), and Slavin (1993)); however, Mourtos (1997) and Smith and Waller (1995) have written on the subject for technical courses. Smith (1993) and Smith and Starfield (1993), suggest that model building is also an essential element of active learning within the engineering classroom. In addition, the ability to work in supportive groups on problems, see for example Astin (1987) and Johnson and Johnson (1989) can be a significant catalyst for improved learning.

Section 2 begins with how to prepare your students for the expectations involved in active and cooperative learning. Section 3 discusses the fundamental components of the cooperative learning paradigm. Section 4 then presents a guide on how to structure the class period to facilitate teaching within this new paradigm. Section 5 illustrates formal cooperative learning exercises for use within the simulation classroom. In Section 6, we discuss some important issues to consider when implementing these methods. Finally, we conclude with a discussion of why we feel that active and cooperative learning should be an essential element in simulation engineering education.

## 2 STUDENT "BUY-IN" TO ACTIVE LEARNING

The most important part in introducing active learning into your classroom is to prepare your students for the change. The active learning is likely to be quite a departure from what students are traditionally used to in the college classroom. In order for active learning to work well, the students should understand what they are about to embark upon and "buy-in" to it.

At the beginning of the term, engage the students in a discussion about how they learn best. Suggest that they may find a clue by thinking about the sensory phases they use most often in conversation. Here are some examples that a person may use that reveal a tendency toward a particular style:

> "I see what you mean."
> "I hear you loud and clear."
> "I need to write that down."
> "I'll think about it."

Invariably, the students will re-create the Meyers and Jones (1993) model of the four major elements of active learning as shown in Figure 1. Some may even confirm research results that suggest students have different learning modalities which can vary from person to person, day to day, and topic to topic (e.g., see McCaulley et al. (1987)). Active learning allows students who rely more heavily on experiential learning to conceptualize and internalize the material presented in class.

After this informal introduction to active learning, it is beneficial to support it with some formal foundation. We suggest that the course syllabus include a brief overview of the active learning philosophy and state your expectations of the students. You should make it clear that the students' participation during class activities is expected and that participation is an integral part of the learning experience in your course. Depending on the level of the students you may want to include some sort of bonus system to reward those students who enthusiastically engage in the process.

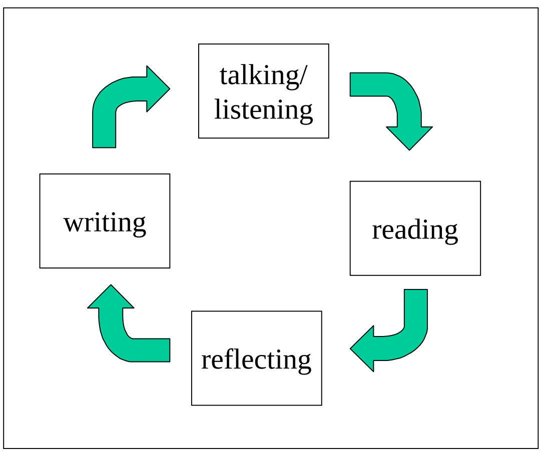


Figure 1: The Four Major Elements of Active Learning

## 3 THE FIVE ELEMENTS OF COOPERATIVE LEARNING

The cooperative learning strategy specifically employs active learning modes. Smith (1994) describes cooperative learning as "students working together to get a job done in a classroom where students are concerned about each other's learning in addition to their own." Johnson, Johnson, and Smith (1991) have characterized cooperative learning as having five basic elements:

1. Positive Interdependence. Positive interdependence refers to the creation of a learning atmosphere in which the success of the group is dependent upon the success of every individual in the group. Simply assigning a group task is not enough. The reward system and the roles of group members must be structured to foster inter-dependence. A very simple technique used by Karl Smith is to provide only one copy of the task to each group. In that way, the group must share the paper and thus become more dependent on one another.

2. Face-to-Face Promotive Interaction. Face-to-Face promotive interaction tries to engage the student in explanations of their learning process to fellow students. The idea is to get students to teach each other.

3. Individual Accountability/Personal Responsibility. Individual accountability addresses the issue of assessing individual student work within the group effort. It goes further than individual assessment. Feedback to the entire group of individual performances is a critical part of individual accountability. An example is to randomly call on a team member to present the group's work. This creates the pressure on the group to ensure that every group member understands the work performed by the group.

4. Collaborative Skills. Collaborative skills refer to the need to teach students how to function within a group. They should have an understanding of group dynamics, active listening methods, conflict-management, and other social skills necessary to function effectively in a group.

5. Group Processing. Group processing tries to engage the students in a self-evaluation exercise. Smith (1994) suggests having the students answer the following two questions: 1) "What is something each member did that was helpful for the group?" and 2) "What is something each member could do to make the group even better tomorrow?"

In different ways, each of these five elements helps students to: impart and receive information, clarify, organize, receive feedback, develop empathy, appreciate different perspectives, test ideas, see connections, create, recognize assumptions, prioritize, etc. The only way students can get all of these jobs done is to get actively involved by using the four main active learning modes (see Figure 1).

There are a variety of ways to structure groups for learning and to incorporate group work into a course.

Smith (1994) classifies groups into three categories. The first is informal learning groups which are "short term and less structured." The second is formal learning groups which are formed around completing a task which might take some period of time. The third is cooperative base groups which are long lasting and supportive in nature. In the next two sections, we discuss informal and formal learning groups in the context of a simulation class. We briefly comment on cooperative base groups in our concluding remarks.

## 4 INFORMAL COOPERATIVE LEARNING AND THE LECTURE

Lecturing is a very effective method for the dissemination of facts and it will undoubtedly remain as a primary component within engineering education. Its effectiveness as a learning tool can be greatly enhanced by reshaping it into a *cooperative learning lecture* that uses informal and formal learning groups.

A schematic on how the cooperative learning lecture proceeds in a one-hour period is shown in Figure 2 (adapted from Smith and Waller (1995)). The backdrop for the class period is three short "mini-lectures" on the topic.

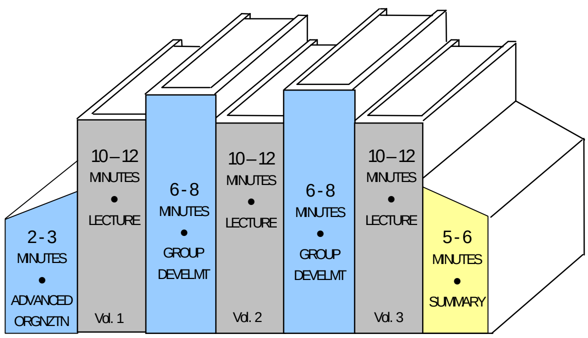


Figure 2: The Cooperative Learning Lecture is Divided into Segments that Promote Active Involvement on the Part of the Students

The lectures are intertwined with the use of small informal groups of students assembled periodically to examine, experience, try, discuss, and understand the topic. To maintain the spirit of the "informal" technique, form the groups spontaneously and mix students with different partners. For example, a simple method is to ask the students to work with the person on their right/left (this is sometimes called the "turn to your neighbor" method in the cooperative learning literature). Alternatively, if class size permits, you may randomly pair the students as they come in the room.

The class meeting begins with an advanced organization activity designed to focus their attention on the session topic. The activity may involve collecting thoughts to contribute to a group discussion on an opening question based the reading or exercises assigned for the day.

The group development work is usually designed around the "think/pare/share" method. In this method, the 6-8 minute segment is subdivided into three parts: (1) a few minutes to think about the question or exercise independently (think); (2) a few minutes to work in the group (pair); and (3) a few minutes to discuss the problem with the entire class (share). The advantage to this approach is that it gives the individual an opportunity to formulate a contribution to the group's work. Furthermore, they feel they *should* make a contribution since they were given the time. While the groups are at work, the instructor circulates around the room to coach and encourage them in their work. Finally, the instructor asks the groups to volunteer their responses. Typical group development tasks include summarizing the material, solving a simple problem, and formulating an example of how the theory applies.

The cooperative learning lecture concludes with a discussion wherein all of the students contribute to a summary of the main points.

Table 1 shows how a complete cooperative learning lecture would proceed on the topic of entity management Students who have prepared the reading for the class session can quickly address Questions 1-3 as an advanced organizing activity. (Students who cannot will quickly get the message that the reading assignment was important.) Questions 4 and 5 in the first group development activity lead to a general discussion on the role of distributions in simulation modeling. Questions 6 and 7 in the second activity lead to an introduction of the particulars in building a simulation model. Notice that in this example, the lecture amplifies the issues that the student groups had just addressed. Other classes may be designed just the opposite so that the group development work amplifies or reinforces the lecture topic.

## 5 FORMAL COOPERATIVE LEARNING ACTIVITIES

Formal cooperative learning groups can last for substantial portions of the class period or even over a span of several class periods. For formal activities that last from 20-30 minutes, the middle three segments (6-8 minute group development, 10-12 minute lecture, 6-8 minute group development) can be replaced with the cooperative exercise. The cooperative exercise becomes the central message of the class period and is supported by an introductory lecture and a summary. We will discuss four formal cooperative learning techniques and use them in examples for a simulation class.

Table 1: Cooperative Learning Lecture Notes on Entity Management

| |
|---|
| <u>Advanced Organization</u><br>1. What names are given to units of traffic in commercial simulation software packages?<br>2. In a model, can more than one unit of traffic move at a time?<br>3. What three conditions may force a unit of traffic to stop moving? |
| <u>Mini-Lecture #1</u><br>• a graphical model of units of traffic<br>• block diagrams<br>• "sink" paths |
| <u>Group Development</u><br>4. What is the difference between an arrival time and an interarrival time?<br>5. How can a sample from a 0-1 uniform distribution be converted to a general uniform distribution? |
| <u>Mini-Lecture #2</u><br>• the simulation clock<br>• base time units<br>• event scheduling |
| <u>Group Development</u><br>6. Write a pseudo-code for a drill-and-casting system that has one drill that must make holes in two castings.<br>7. Identify in your code steps where a unit of traffic must actually move. |
| <u>Mini-Lecture #3</u><br>• block statements<br>• control statements<br>• comment statements<br>• model files |
| <u>Summary</u><br>The creation, movement, and destruction of units of traffic in simulation models. |

### 5.1 Problem Solving

Event graph diagramming and activity cycle diagramming are two commonly used techniques for specifying a language independent representation for a simulation model. A traditional approach to these methods is to explain the symbols and notation involved in the diagramming technique and then to illustrate the technique on a simplified example. Examples are an excellent opportunity for activating the classroom. Why should the students passively watch as the example is covered? Instead, setup an activity based on the example and then facilitate the student groups as they work through the example. Table 2 illustrates a cooperative exercise for activity cycle diagramming.

Table 2: Activity Cycle Diagramming

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|---|
| <u>Objective:</u> To allow students to practice activity cycle diagramming |
| <u>Setup:</u> Assumes familiarity with basic symbols and notation of activity cycle diagramming. Ask students to count off 1,2,3, 1,2,3, etc. Each sequence of 1,2,3 forms a group. |
| <u>Activity:</u> Take 3 minutes individually to read the following system description from Davies and O'Keefe (1989).<br><br>Suppose we have a hospital with a ward such that the number of beds acts as the constraining resource. Patients who are identified as needing treatment are admitted to the ward, acquire a bed for treatment, and then are discharged. If a bed is not available in the ward the patient is placed on a waiting list. In this system, some patients require planned operations and some do not. They have their own separate arrival processes, and they join different waiting lists for entering the ward. Assume those patients that do not require an operation are to be given priority for an available bed. The operating room may also constrain the number of admissions to the ward. Patients who require an operation are put in a waiting list for the operating room after they have acquired a bed. There is only one operating room which is sometimes shut and sometimes open. After a patient has received their operation, they return to their bed for a post operative stay and then they are discharged.<br><br>1. Individually draw a pictorial representation for this system, e.g. rich picture. (3 minutes)<br>2. As a group, draw an activity diagram for the system. Clearly label the entities, queues, and resources. (10 minutes) |
| <u>Accountability:</u> Randomly select 1 group of students and then randomly select 1 person from the group to place their diagram on the board and to explain their answer. (5 minutes) |

As the subject matter difficulty increases it becomes important to break the task down into smaller steps. For example, on the activity cycle diagram exercise, there are two steps to the task. A further refinement would be to have the students first list out either individually or as a group the resources, entities, queues, and attributes. Then, the students can begin the drawing. The instructor circulates to clarify the symbols or any misconceptions about the system.

### 5.2 Student Role Assignment

Table 3 introduces the idea of having clearly defined roles for the members of the group. Roles help to codify interdependence, collaborative skills, accountability, responsibility, and group processing.

Table 3: Hit or Miss Estimation

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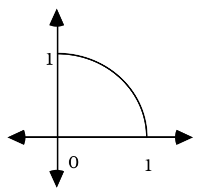
|---|
| Objective: To motivate the students in the use of Monte-Carlo methods and allow problem solving and algorithm development practice. |
| Setup: Ask students to count off 1,2,3, 1,2,3, etc. Each sequence of 1,2,3 forms a group. The "1" person is to be the **Recorder**, the "2" person the **Facilitator**, and the "3" person the **Quality Checker**. The Recorder gets this problem sheet and records the groups answer. The Facilitator asks for rationale, elaboration, and generally questions assumptions of the model. The Quality Checker makes sure each member participates and is responsible for checking the quality of the product and process. Remember these roles are in addition to each person's responsibility to help to solve the problem. |
| Activity: Write pseudo code to estimate the value of $\pi$. Assume that you have a random number generator or function available which will generate random numbers in the interval [0,1]. In addition you have the information contained in the diagram.   $\frac{\pi}{4} = \int_0^1 \sqrt{1-x^2}\,dx$ Do not use books as a reference; however, do use your class notes. Take 3 minutes individually to sketch out your idea for the solution, then formulate your group answer. You have 10 minutes. If your group gets done early, look around for another finished group and compare your solutions. |
| Accountability: Randomly select two pairs of students and then randomly select one person from each pair to place their solution on the board and to explain their answer. |

### 5.3 Jigsaw Strategy

As an illustration of another type of formal cooperative learning procedure, Table 4 illustrates the jigsaw strategy. In this strategy, each member of a group is given a different section of the material to learn (Aronson (1987)). The members are dependent upon each other to learn all of the material. This is accomplished through student to student teaching. In essence, this strategy works on the premise that in order to teach material you must first fully understand the material. Secondly, this strategy uses the concept of divide and conquer. This enables a larger quantity of material to be covered while still promoting positive interdependence. When using this strategy, it is important for the instructor to interact with the students. For example, the instructor may want to require a draft of the teaching material be turned in for review and comment.

Table 4: Material Review

| |
|---|
| Objective: To have students learn and teach each other material. |
| Setup: Divide material into X sections. Randomly place students into groups with X members. Randomly assign each student in each group a section to cover. |
| Task: Your task in this group is to learn all of the material in Chapter 2 of Banks et al. (1996). Work cooperatively to ensure that all members of the group master all of the material.<br>Find a member in another group who has the same section as you. Work with that person to master the material. Develop a method to teach the material to other members in your group. Prepare visual aides for explaining the material. Plan active roles for your group members. Teach your groups members.<br>Find another pair with the same section of material to present. Review all materials. Revise both pair's materials using the best material from both presentations. |
| Accountability: During class, randomly select 1 group of students. Working with their paired partner have each member of the group teach the entire class their material. Each student pair is responsible for turning in their teaching materials. |

### 5.4 The Student Tutor

Table 5 illustrates how to incorporate a simulation language and computer demonstration into an active learning experience. Instead of having the students explain their solutions to the entire class, you can have each group member explain the group's answer to a member of another group.

## 6 IMPLEMENTATION ISSUES

After using cooperative learning strategies in the classroom, we have identified several issues that need to be considered for smoother implementation.

**Teachers' roles**: Although the teacher may move to the background during class time, s/he actually has a much more expanded role in the active learning process.

Table 5: Introducing Simulation Languages

| |
|---|
| <u>Objective:</u> To have students solve their first simulation problem using initial ARENA constructs. |
| <u>Setup:</u> Assumes familiarity with basic constructs such as servers and arrivals from the ARENA common panel. Ask students to count off 1,2,3, 1,2,3, etc. Each sequence of 1,2,3 forms a group. |
| <u>Activity:</u> Take 10 minutes individually to read the following system description from Banks et al. (1995).<br><br>Jobs are started at a production area according to an exponential distribution with a mean of 5 minutes. The production process consists of three operations: drilling, milling, and grinding. There are 2 drills, 3 mills, and 2 grinders. The drills and grinders can have a maximum of 2 jobs waiting in the queue to be processed, and the mills can have up to three.<br>Upon arrival to the drill area, a job is processed for 6 to 9 minutes uniformly distributed. The job is then milled with a process time that is triangularly distributed with a minimum, mode, and maximum of 10, 14, and 18, respectively. Lastly, the job is processed in the grinder area according to the following discrete distribution: 25% require 6 minutes; 50% require 8 minutes, and 25% require 12 minutes.<br>Jobs that cannot enter a queue due to capacity limitations are ejected from the system. Transportation times between resources are assumed to be negligible. Random number stream 1 is used for all processes and arrivals.<br><br>Simulate the system for 40 hours and answer the following:<br>1. How many jobs are completed?<br>2. What is the utilization for each resource?<br>3. What is the total number of jobs ejected due to full queues?<br>4. What is the average number of jobs in each queue?<br>Steps:<br>1. Individually draw a pictorial representation for this system, e.g. rich picture.<br>2. As a group, draw an activity diagram for the system. Clearly label the entities, queues, and resources.<br>3. Make a list of the ARENA constructs from the common or support panels needed to model this system. For each construct, clearly identify the dialog entries required. |
| <u>Accountability:</u> Randomly select one group of students. Have the group use the computer to input their model. They are to verbalize their process for the class. Each person in the class is responsible for turning in a completed model for the next class period. |

Smith (1994) suggests this role has five elements: (1) setting instructional objectives; (2) pre-instructional decisions including the forming of groups, materials, and group roles; (3) explain task and cooperation; (4) monitoring and intervening to help with cooperation skills and learning; and (5) evaluating and processing of the learning and group interaction.

**Molding Groups into Teams:** Many teachers think that they are already using cooperative learning because they allow the students to work in groups. Successful cooperative learning is not just group work, it incorporates the five elements of cooperative learning in a synergistic manner. Without each of these elements group work can actually be a hindrance to student learning (see Smith (1995) for a further discussion of this point). An objective of cooperative learning is to have groups of students that work in teams. Katzenbach and Smith (1993) define a team as:

*"A small number of people with complementary skills who are committed to a common purpose, performance goals, and approach for which they hold themselves mutually accountable."*

We have found that randomly picking the groups or picking groups based on student attributes can facilitate learning and team formation better than having the students form their own groups.

**Teachers' responses to cooperative learning:** Many educators express three frequent responses to the cooperative learning approach. One is uneasiness about "giving up control" of their classrooms. The second is that cooperative learning may sacrifice the amount of material that can be "covered" in a course if class time is turned over to student work. The third is a feeling that they are not fully doing their job unless they are giving a polished lecture (Monk (1983)).

It is true that some of the spotlight is relinquished to the students during the class but student motivation often increases with this added responsibility. We have found that we can still investigate the same topics as before using cooperative learning because the students learn more effectively and at a deeper level. Even if the quantity of material is not the same, the quality of understanding is vastly improved. Designing the cooperative learning class takes a significant amount of preparation time because it requires careful development of the student activities in addition to developing the lecture.

**Individual and group assessment:** Good methods are needed assess an individual's learning within a group experience. Groups need to be monitored and structured so as to prevent less motivated students from "riding the coat tails" of the more effective team members. The examples presented in this paper represent techniques for use in the classroom. If cooperative learning activities are used as homework or projects then grading is an issue that must be seriously addressed. Johnson, Johnson and Smith (1991) cover grading in cooperative settings. A couple of key points to remember: 1) use a criterion referenced absolute scale (don't curve) and 2) structure the grading so that cooperation does not penalize the student. For example, give bonus points to each member of a team if the individual team members' scores are sufficiently high.

## 7 CONCLUDING REMARKS

The Boyer Commission Report (1998) on Educating Undergraduates in the Research University strongly suggests that research universities move towards inquiry-based methods of teaching in order to engage undergraduates actively in the research process. Consider Webster's 7th Dictionary's definition of research:

*"studious inquiry or examination; esp.: investigation or experimentation aimed at the discovery and interpretation of facts, revision of accepted theories or laws in the light of new facts, or practical application of such new or revised theories or laws."*

Websters defines learning as:

*"to gain knowledge or understanding of or skill in by study, instruction, or experience."*

Research is something that is performed -- it is an active process. The ultimate goal of research is to gain knowledge about the topic under consideration (learning) and then to formulate and present an interpretation of what has been learned (teaching). Now, compare this to Thompson and Jorgensen's (1989) discussion of how knowledge is gained during active learning, "knowledge is *directly* experienced, constructed, acted upon, tested, or revised by the learner" (emphasis added). In other words, the researcher and the learner are one in the same. The active learning paradigm attempts to shift students from the passive mode of receiving knowledge to the active role of generating, synthesizing, understanding, and applying knowledge. By using the active model within the classroom, we can move towards The Boyer Commission's blue print for undergraduate education.

The goal of using cooperative learning in the classroom is to make the student stronger through interaction and communication around the process of academic inquiry. Students improve their thinking and problem-solving skills. To professional engineers, the ability to actively identify, formulate, and solve problems is essential to a successful career.

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