Proceedings of the 1997 Winter Simulation Conference
ed. S. Andradóttir, K. J. Healy, D. H. Withers, and B. L. Nelson

ACTIVATE THIS CLASSROOM AT TIME NOW

Manuel D. Rossetti

Department of Systems Engineering
University of Virginia
Thornton Hall
Charlottesville, Virginia 22903, U.S.A.

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 students learn best by doing and working with each other. This paper presents background information on active and cooperative learning techniques at a practical level for immediate incorporation into simulation education. Tips and examples for how to transform a standard lecture into a cooperative exercise are given and the author's experiences with these techniques are detailed.

1 INTRODUCTION

After many years of undergraduate and graduate studies in Industrial and Systems Engineering, my grandmother once asked me: "Don't you know that stuff yet?" I never really had a good reply until after graduating with my Ph.D. My response was an emphatic, "No!" I came to the realization that all those years of study had enabled me to understand that I knew very little compared to what could be known. I realized that through the activity of pursuing advanced degrees that I had taught myself how to learn. I also realized that teaching, learning, and research are intricately inter-related and synergistic. This also led me to form the following hypothesis: *learning is an active process not a passive process*. I had learned by doing research, by teaching during graduate school, and by actively pursuing new knowledge.

I then had the opportunity to attend a seminar on active and cooperative learning by Karl Smith from the University of Minnesota. The material presented confirmed my hypothesis that learning is an active process not a passive process. The seminar also opened my eyes to the fact that I was not the only one with the same hypothesis. Consider the following question: "In the traditional lecture-based college classroom, who does the most learning?" One might hope that the students are doing the most learning, but is this really the case? The professor actively reads class materials, synthesizes the material into a lecture, presents the lecture, and reflects on feedback from students concerning the lecture. The professor does the majority of the work and probably the majority of the learning.

Since that time, I have predicated my teaching on methodologies which actively engage both the teacher and the students into the process. The teacher serves as a facilitator and resource, the students interactively learn from each other, from the teacher, and from the process itself. Students have different learning modalities which vary from person to person, day to day, and topic to topic; therefore, it is essential to use a variety of techniques in order to be effective. 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. I then present a guide on how to make the shift from the passive model to the active model. The active model is then illustrated through examples and I conclude with a discussion of some of the important issues to consider when implementing these techniques.

2 BACKGROUND

Consider Websters 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, i.e. it is an active process. The ultimate goal of research is to gain knowledge about the topic under consideration, i.e. to learn about the topic and then to formulate and present an interpretation of what has been learned, i.e. to teach about the topic. Now, compare this to Thompson and Jorgensen's (1989) discussion of how knowledge is gained during active learning, "knowledge is *directly* (emphasis added) experienced, constructed, acted upon, tested, or revised by the learner." 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.

Why then do many college professors rely on the standard lecture as the primary mechanism for instruction. The lecture allows us to remain in the researcher role, since as previously mentioned, we are responsible for generating, synthesizing, understanding, and presenting the knowledge to the students. In addition, the lecture model is the model that we most commonly experienced as students. I am not advocating the replacement of the lecture model. I am suggesting that by incorporating active and cooperative learning techniques into a lecture one can better serve the variety of learning modalities which research, see for example, McCaulley et al. (1987), has shown to exist in the engineering classroom.

Meyers and Jones (1993) suggest that talking/listening, writing, reading, and reflecting are four major elements of active learning. In different ways, each of these activities 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. Additional research, see Smith (1993) and Smith and Starfield (1993), suggests 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.

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
2. Face-to-Face Promotive Interaction
3. Individual Accountability/Personal Responsibility
4. Collaborative Skills
5. Group Processing

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 during his seminar was to only provide one copy of the task to each group. In that way, the group had to share the paper and thus become more dependent on one another. 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 teaching each other. 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. Collaborative skills refers 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. Finally, group processing tries to engage the students in a self evaluation exercise. Smith (1994) suggest 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?"

There are 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.

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 listed above in a synergistic manner. Without each of these elements group work can actually be a hindrance to student learning, see Smith (1995). In a sense, cooperative learning uses teams of students not groups of students. 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."

In the next section, I present some simple strategies for implementing cooperative learning in the simulation classroom.

3 MAKING THE SHIFT

Getting started with cooperative learning methods is not as hard as it may seem. The best advice is to proceed slowly in an iterative fashion by incorporating mini-activities into strategic locations within a lecture. With each presentation of the lecture, take the opportunity to add additional activity based material or to fix old activities which did not achieve their intended purpose. Perhaps the easiest method is the "turn to your neighbor" strategy or as it is sometime called "think-pair-share." This informal group strategy consists of a short task (3-5 minutes) which is given to pairs of students. Typical tasks include summarizing the material, solving a simple problem, and formulating an example of how the theory applies. This strategy is also a good mechanism for starting discussion and allows the students to get comfortable with each other.

In simulation, there are often many definitions which must be understood so that communication may occur at a more productive pace. For example, we often refer to words such as event, state, activity, entities, resources, processes, etc. Instead of displaying these definitions, ask the students to: individually define the word, pair with a neighbor, compare definitions, and then consolidate to one definition. As the instructor, one can then randomly select students from different pairs to place their definition on an overhead and then ask each pair to compare and contrast the definitions with their own. This discussion can also be used to present a more formal definition on the overhead or to indicate where the students can find the traditional book definition. This technique will also work with more mathematical concepts especially at the graduate level. In this case, one can specify that a more precise mathematical definition is needed.

The next step is to develop activities for formal cooperative learning groups. These groups can last for the entire class period or over a span of several weeks. Smith (1994) suggests that the role of the teacher contain the following five elements:

- setting instructional objectives
- pre-instructional decisions including the forming of groups, materials, and group roles
- explain task and cooperation
- monitoring and intervening to help with cooperation skills and learning
- evaluating and processing of the learning and group interaction

Smith (1994) also presents a lesson template for incorporating problem solving activities into the classroom. Other techniques include structured controversy, see Johnson, Johnson, and Smith (1986) and the jigsaw strategy, see Aronson (1987).

Finally, cooperative base groups can be incorporated into the entire course experience. Cooperative base groups consist of three to four students which function as a support group. They give each other assistance, encouragement, and feedback in the mastering of the material. They are responsible for ensuring that all members of the group have mastered the material and can provide a mechanism for performing course evaluation, see Schwartz (1996).

In the next section, I present illustrative examples of informal and formal cooperative learning exercises used within my undergraduate and graduate classes in simulation.

Exhibit 1: System Definition Concepts
Objective: Allow students to internalize definitions
Setup: Assumes familiarity with basic definitions. Ask students to form pairs.
Activity: Take 1 minute individually to review the definitions of entity, attribute, event, activity, and state variable. Take 2 minutes to list as many entities, events, activities, and state variables as you can for a Grocery Store. Share your list with your partner. Discuss your assumptions. With your partner, create a new list and explicitly list your assumptions. When you complete the activity compare your list with another group's list.
Accountability: Randomly select 2-3 pairs of students and then randomly select 1 person from each pair to place their list on the board and to explain their answer.

4 SIMULATION CLASSROOM EXAMPLES

This section presents four examples of collaborative exercises which move from basic material to the more involved concepts within simulation. The first example given in Exhibit 1 is a turn to your neighbor activity utilized after a discussion of the meanings of entities, attributes, events, and state variables has occurred. As an alternative to asking students to make their own pairs, one can ask students to count off and then match up with the person next in numerical sequence.

As the teacher, it is important to listen in on the discussion of as many pairs as possible. When visiting each group, ask questions about their list and try to reemphasize the connection to the definitions. A grocery store is a rather vague system. This should create some tension for the students. Clearly, the identification of entities, attributes, etc. depends on the objectives of the study. Some pairs will not make this connection, this presents an opportunity to volunteer items for their list which may be valid under a different objective in order for them to make the connection.

Exhibit 2: Activity Cycle Diagramming

Objective: To allow students to practice activity cycle diagramming

Setup: 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.

Activity: Take 3 minutes individually to read the following system description from Davies and O'Keefe (1989).

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.

1. Individually draw a pictorial representation for this system, e.g. rich picture.
2. As a group, draw an activity diagram for the system. Clearly label the entities, queues, and resources.

Accountability: 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.

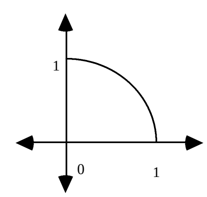
Event graph diagramming and activity cycle diagramming are two commonly used techniques for specifying a language independent representation for a simulation model. A traditional approach to these methods is to explain the symbols and notation involved in the diagramming technique and then to illustrate 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. Exhibit 2 illustrates a cooperative exercise for activity cycle diagramming.

Exhibit 3: Hit or Miss Estimation

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 π. 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 Figure 1.



$$\frac{p}{4} = \int_0^1 \sqrt{1-x^2}\,dx$$

Figure 1

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 2 pairs of students and then randomly select 1 person from each pair to place their solution on the board and to explain their answer.

I have found that 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, I have added 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, they can begin the drawing. As the instructor, I circulate among the groups to clarify the symbols or any misconceptions about the system. With activity cycle diagramming exercises, I often get questions about how students can represent something that is not in the basic notation. At the undergraduate level, I allow them to augment the diagram in any way they find appropriate. At the graduate level, I use this question to point them to literature which discusses further refinements.

Exhibit 3 introduces the notion of having clearly defined roles for the members of the group. Roles help to codify interdependence, collaborative skills, accountability, responsibility, and group processing. Katzenbach and Smith (1993) state the importance of roles to effective team work as follows:

"Effective teams always have team members who over time, assume important social as well as leadership roles such as challenging, interpreting, supporting, integrating, remembering, and summarizing."

As an illustration of another type of formal cooperative learning procedure, Exhibit 4 illustrates the jigsaw strategy. In this strategy, each member of a group is given a different section of the material to learn. 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.

Exhibit 5 illustrates how to incorporate a simulation language and computer demonstration into an active learning experience. A variation on having the students explain their solution to the entire class is to have each group member explain the group's answer to a member of another group. In addition to these examples, I have created exercises for writing events, hand simulation, random number and variate generation, and for the understanding of confidence intervals.

5 CONCLUSIONS

After utilizing cooperative based learning strategies within the classroom, I have identified four major issues which need to be considered when implementing the techniques. The issues are: 1) Methods to perform individual and group assessment: 2) Amount of material covered versus quality of learning: 3) Graduate level versus undergraduate level: 4) Methods to form groups to enhance learning.

Exhibit 4: Jigsaw Strategy
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. Find a member in another group who has the same section as yourself. 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. 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.

Methods are needed to better 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) covers 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 members scores are sufficiently high.

I have also found that activity based learning takes time. A tradeoff exists between how much material one can cover in a semester versus the quality of learning. One of the best places to do group activities is within the classroom to break up the standard lecture. These mini-activities during the class period reduce the volume of material that can be transferred to the student, but they also increase the student's motivation and understanding of the material presented. In designing a course for the graduate level, the sophistication of the activities can be increased. The material at the graduate level is more integrative as compared to undergraduate material.

Exhibit 5: Introducing Simulation Languages
Objective: To have students solve there first simulation problem using initial ARENA constructs.
Setup: 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.
Activity: Take 10 minutes individually to read the following system description from Banks et al. (1995). 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. 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. 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. Simulate the system for 40 hours and answer the following: 1. How many jobs are completed? 2. What is the utilization for each resource? 3. What is the total number of jobs ejected due to full queues? 4. What is the average number of jobs in each queue? Steps: 1. Individually draw a pictorial representation for this system, e.g. rich picture. 2. As a group, draw an activity diagram for the system. Clearly label the entities, queues, and resources. 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.
Accountability: Randomly select 1 group of students. Have the group of students 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.

I feel that it is critical that the current crop of graduate students be introduced to this learning method. Many of today's highly technical problems require professionals who can do research within a team environment. Graduate students also go into the teaching ranks. They need to have experience with and confidence in these innovative teaching methods in order to feel comfortable utilizing them in their teaching careers. Active and collaborative learning fits nicely with Problem Based Learning (PBL), see Wood (1994), which places the problem as the starting point for contextual learning. This should be contrasted to subject based learning which shows the theory first and the application second. To professional engineers, the ability to identify, formulate, and solve problems is essential to a successful career.

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AUTHOR BIOGRAPHY

MANUEL D. ROSSETTI is an Assistant Professor in the Systems Engineering Department at the University of Virginia. He received his Ph.D. in Industrial and Systems Engineering from The Ohio State University. His research interests include the design, analysis, and optimization of manufacturing, health care, and transportation systems using stochastic modeling, computer simulation, and artificial intelligence techniques. Dr. Rossetti is an Associate Member of the Institute of Industrial Engineers and a member of the IIE OR Division. Dr. Rossetti is also a member of INFORMS and SCS.