Incorporating Active Learning and Information Technology into a New Introduction to Environmental Engineering Course

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Abstract

A new Introduction to Environmental Engineering Class was designed to use active learning techniques in the classroom. A discussion of active learning and a summary of advantages that have been discussed in the literature are included in the paper. Before the decision was made to use active learning extensively in the classroom, a number of concerns had to be considered. Some of the primary concerns are discussed in the paper. Examples of different active learning exercises are provided. Because a considerable amount of time is often required to conduct meaningful active learning exercises, computer resources were used to present information in the classroom and disseminate information to students outside the classroom. This helped to provide the degree of efficiency that was needed to provide a balance between the significant amount of time required to use active learning exercises and still present the course material in the classroom. Based on an assessment from an independent (faculty) observer, the use of active learning proved to be an excellent format for the class, providing a learning environment that promoted enthusiasm and participation from a large percentage of the students.

Introduction

During the last few years, the Department of Civil and Environmental Engineering at The Citadel has conducted a self-assessment of its curriculum, resulting a number of changes that are currently being implemented. One of the new courses that has resulted from the curriculum change is called Introduction to Environmental Engineering. The new course is taught in the first semester of the junior year and is followed by a number of courses in water resources/environmental engineering. Many environmental concepts that are now introduced at the beginning of the junior year were previously not introduced until the senior year under the old curriculum.

Besides goals directly associated with the course material, a number of additional goals were adopted for the class, including improved learning compared to a "typical" course, improving the grades of weaker students, higher retention of course material in the classroom, improving self-confidence of students, supportive interaction among students in the academic environment, and increased interaction between faculty and students. Most of these are results that many claim can be achieved through effective cooperative or active learning techniques.

As I (Brannan) pondered these goals and how to achieve them, I considered whether to implement active learning extensively in the classroom. After all, I had attended numerous sessions at the national and sectional ASEE meetings devoted to active learning, read "how to" books and articles on the subject, and attended workshops taught by experts in the field. However, I had, to a limited extent, tried active learning in various courses and had experienced both success and failure with cooperative learning groups. The failures made me apprehensive about attempting these techniques on a much larger scale in a new class - a class that I felt would be a critical initial experience for students in the environmental area. In spite of the perceived risks, I decided that the past failures were correctable and made the decision to conduct classroom sessions with less lecture time and more time devoted to active learning. Further, I decided that I would place a high priority on active learning sessions: these sessions would *not* be canceled to buy time to "cover all the material" in the classroom.

This is a valid concern for anyone considering using active learning techniques: regardless of how valuable active learning sessions are, they take up precious classroom time. During the brief lecture sessions, it is important to be both efficient and effective. I decided to take advantage of information technology to help make lecture time efficient and effective.

This paper discusses the incorporation of active learning techniques into the Introduction to Environmental Engineering class and the use of information technology for classroom instruction and disseminating information outside the classroom. As an initial assessment of how well all this worked in the classroom, co-author Dennis Fallon offered to serve as an independent observer in the classroom. In the final section of this paper, he discusses his observations and

provides additional insight for those who may be considering active learning techniques in the future.

Background

Prior to the curriculum change, the environmental/water resources sequence consisted of two lecture courses: Fluid Mechanics and Water and Wastewater Systems. Each lecture course was supported by a separate laboratory course. Thus, apart from fluid mechanics, most lecture material in the environmental area was packed into a single senior-level course. Two additional environmental courses were added to the junior-year offerings as a result of the curriculum change: Introduction to Environmental Engineering and Hydrology and Water Resources. Introduction to Environmental Engineering is a three-hour course that introduces students to risk assessment, environmental legislation, water quality and pollution control, solid and hazardous waste, air pollution and control, noise pollution, environmental assessment, and social and ethical considerations. The coverage of subjects in Introduction to Environmental Engineering is intentionally broad and is followed by more in-depth coverage of certain topics in the remaining courses.

Active Learning

James Stice[1], one of the country's leading mentors of effective teaching in the engineering classroom, relates some interesting statistics on retention based on data from the Socony-Vacuum Oil Company. The lowest retention took place when information was received in a single mode: reading (10 percent), hearing (26 percent),and seeing (30 percent). Retention was improved significantly by hearing and seeing (50 percent), saying something (70 percent), and saying something and doing something (90 percent). Clearly, designing a class to take advantage of multiple learning modes and keep students active can potentially enhance learning and motivate students.

One way to achieve a balance between transmitting information to students and keeping them active is to design periods of lecture followed by active sessions. Active sessions can include discussion/debate, writing assignments or short quizzes, working problems, analysis of concepts previously discussed, and brainstorming, to name a few examples.

Active learning can be done individually or in groups. Design of group structure and execution of group activities are keys to success for groups. Groups that function with cooperative learning techniques have been demonstrated to be effective in enhancing learning in a considerable number of studies[2,3,4]. The literature on cooperative learning strongly stresses that simply placing students in groups and providing a task is not necessarily true cooperative learning. Five elements have been identified as essential to effective cooperative-learning groups[3,5,6].

- **Positive interdependence**: Students must depend on each other to successfully complete activities; each individual must sense that success is not possible without his or her contribution.
- **Face-to-face promotive interaction**: Activities should be organized to promote a definite interchange of information among group members; this will allow group members to challenge and learn from each other through brainstorming, explaining concepts, refining ideas, etc.
- **Individual accountability**: Each student must be held accountable for his or her contributions and for learning material; examples include individual tests and random questioning of group members.
- **Small group skills**: Group members must develop leadership, communication, conflict-management, decision-making, trust-building, and other essential teamwork skills.
- **Group processing**: Each group should occasionally assess how well it has met goals set by the group, and identify any changes that should be made in the future as well as what should be continued.

Initial Concerns

Even after the new curriculum had been approved, I had well over a year to contemplate the format that would be used for the new course. After gathering information from a variety of sources about active learning, including cooperative learning groups in particular, I discovered that there were generally two camps with regard to this teaching style: those who feel strongly that the use of active learning is superior to traditional classroom techniques and those who feel strongly that the use of techniques such as cooperative learning groups is less effective than the traditional classroom and may in fact hinder individual achievement. In the college engineering classroom, the conscientious teacher should be able to address this last concern by providing individual accountability and designing a certain percentage of challenging individual assignments.

With a substantial amount of information in hand, I felt enthusiastic about the potential of a class that fully utilized active learning but at the same time I held a number of concerns. One of the major concerns that I had was whether the benefits would really be worth the considerable amount of time required to properly manage an active-learning class, particularly during the first year of the course. I had observed and participated in active-learning classes in

the past and it was clear to me that planning a successful class may be very time-consuming. Also, I had seen successful active-learning exercises during workshops take far more time that the coordinator planned, and I wondered if it would be possible to maintain a schedule that would adequately meet the objectives of the course. This concern was addressed to a great extent by taking advantage of computer presentation software, which helped make the presentation of course material efficient enough to provide more time for active-learning exercises. I addressed some of the uncertainty in time required for the exercises by planning ahead what course material could be either eliminated or assigned as reading material and by identifying several potential active learning exercises from which I could select during class, depending on the time remaining in the class. Some subjects were introduced as "challenge problems" from which students could earn extra credit if they did the reading and worked the problems. Many students took advantage of this opportunity.

Another concern I had related to my past experience with groups: certain students seem to get a "free ride" and not learn the course material. I realized that the primary reason this had happened in the past was that I did not ensure positive interdependence - i.e., each member of the group did not have a specific task and group members did not necessarily rely on each other for the success or failure of group activities. During the first few days of the Introduction to Environmental Engineering class, I made sure that each group member had a task. I helped maintain individual accountability by randomly selecting a group and then randomly selecting an individual to describe the contributions made by that individual. Similarly, for problem solving exercises I randomly selected a group, and then randomly selected a person to describe the group's solution to the problem.

One question I had was whether to limit active learning to the classroom or to extend it to out-of-class assignments. Felder and Brent[4] reported on a highly successful effort in a chemical engineering sequence where groups were required for out-of-class assignments. Others have decided not to use out-of-class group assignments because commuter students would have trouble meeting with groups. I decided to begin the class using in-class active-learning exercises. For homework, I allowed problems to be done either individually or in a group. The only stipulation was that if a problem was completed as a group project, everyone in the group had to participate or everyone in the group must complete the problem individually. This policy provided an opportunity to talk to the class about the potential advantages associated with groups and to prepare them mentally for their first *required* group assignment, which came several weeks into the course.

A legitimate concern any teacher might have would be whether students would be critical of the teacher for "getting out of work" when the opposite is actually true. I expected this and decided to periodically educate the class on benefits associated with active learning. I intentionally did very little of this on the first day of class. Instead, I waited until about a week before the first test. Discussion on improving learning and grades seemed to have significant impact at that time.

Although I had a number of concerns that are not discussed in this paper, I was relieved to discover that there were others who had these same concerns and who had experienced some of the same difficulties that I had experienced. I was especially encouraged by the report by Felder and Brent[4] in which many potential problems and solutions are discussed in detail. Finally, I decided that I had to accept a certain risk to have an opportunity to reap potential benefits.

Organizing Groups

A number of different schemes for structuring collaborative groups has been proposed, but in general there are three types of groups[3]: informal groups, formal groups, and base groups. Informal groups are assembled during one class period or shorter. Activating such groups after approximately every fifteen minutes of lecture can help students to refocus on course material and potentially learn more in the process through active participation. Formal groups are organized to work on a specific assignment and may last an entire class period or longer. Groups may be reorganized after completing the task. Base groups are long-term groups that have the potential for providing members with mutual support.

The size of groups should be small, approximately 2 to 4, unless the assignment is complex enough to require more members. For longer tasks, group membership should be heterogeneous; that is, composed of individuals of varying ability levels[4,6]. It is usually recommended that teachers select the groups instead of having students organize the groups[4,6].

My initial intention was to carefully follow the advice in the literature. I organized informal groups on the first day of class for activities planned after short periods of lecture. Students completed a questionnaire that I planned to use in forming what I called "base groups." These were groups that would work together on problems that were begun in class and continued outside of class. It was my intention, that once organized, the base groups would work together for the remainder of the semester. I used the information

provided by the students to put together base groups of three members. Each group was composed of individuals of differing ability levels. I made sure that there was one person in each group who had high grades and/or high grades in mathematics courses. After about two to three weeks of working with informal groups, I announced the make-up of the base groups. The students received the announcement with much less enthusiasm than I had seen in the informal groups in the first few lessons. I discovered that although I had followed the advice given in the literature, I had not considered the military structure of the school. This year, students are required to remain in their barracks after 10:30 PM. The groups I assembled contained students who lived in different barracks, and this placed constraints on when they had to meet under a rigid military daily schedule. It was clear to me after talking to several students that motivation was not very high, and I decided that high motivation must take priority over guidelines in the literature. I placed the matter before the class and the students overwhelmingly encouraged me to revise the group make-up to allow them to be in a group with students in the same barracks. Eventually, I allowed the students to form their own groups, with the advice that they should make sure that at least one member of the group had strong mathematics skills. After reviewing the composition of the groups, I found that most of the groups were reasonably heterogeneous.

Group Activities for Active Participation

Cooperative learning groups may be designed to achieve a number of different purposes. Much variety can be incorporated into classes by using a wide range of exercises. Groups may be used to review short lecture modules or concepts from the previous class period, to preview or introduce material that will be discussed next, for setting up or solving problems, for analyzing concepts or procedures, or for brainstorming. Other possible group activities include providing applications to theoretical concepts discussed in class, predicting what the next step or next topic will be based on the preceding discussion, suggesting answers to questions posed, listing concepts from a lecture that were not understood, generating questions on the course material, and structured controversy. Examples of selected group activities that may be used in an introduction to environmental engineering course are provided in Table 1.

One simple method that encourages both individual and group learning is called "think-pair-share." Students individually formulate the solution to a problem; pairs are then formed where each student shares his or her solution while the other person carefully listens; finally, the two students develop a new solution. Groups of three members, or four for more complex tasks, can also be used effectively in a variety of activities.

A special type of group that may be used as an alternative to lecture is called "jigsaw[7]." Each member of a group is assigned specific material on which to become an expert. Students then team with members of *other* groups who are working on the same material to cooperatively develop expertise on the assigned subject. After adequate preparation, each member returns to his or her group and teaches the material to the other group members.

Information Technology: In and Out of the Classroom

Out of the Classroom

Dissemination of information outside the classroom was accomplished through a World Wide Web site located on

Table 1. Selected Examples of Group Activities

Type Group Activity	Example Assignment
Review	"List as many parameters as you can remember for monitoring water quality and be prepared to explain the significance of the parameter monitored."
Preview	"Each group has a copy of a small subdivision in the planning stages. Sketch in a sewer system to collect wastewater from houses to be constructed. Feel free to consult the chapter we will be studying today or ask me any questions that you may have."
Solving Problems	"Solve Problem 15 at the end of the chapter. Make sure every member of the group can explain how the carbonaceous and nitrogenous BOD is determined from the graph. Any student in a group to be selected at random may be asked to explain the group's solution."
Analysis	"Each group has a copy of a laboratory report of tests conducted on raw wastewater. Based on what we have studied during this period, identify any errors you find in the results."
Structured Controversy	"There are several potential viewpoints on the environmental ethics situation you just heard. Each base group will be assigned a specific viewpoint, and must be prepared to defend that viewpoint in an oral presentation at the beginning of next period. The group's defense must be summarized in a written paper to be handed in."
Brainstorming	"List as many ways as you can in which engineers may need to evaluate risk."

the department's server. Students could access the site from computer laboratories on campus, barracks, and off-campus sites. Information about the course, a course syllabus, how to contact professors, professors' daily schedules, class policies, information on base groups, and grading were available on the site. Additionally, students could download course notes, example problems worked in class, information on homework problems and challenge problems, information on upcoming tests, and test solutions (posted following the test) from the web site.

Course notes and example problems were created using Acrobat Exchange© and stored as pdf files. Notes and problems were normally placed on the site prior to class so students could, if they wished, download the files and print a hard copy to use in class. Alternatively, students could view the files on computer monitors using Acrobat Reader© at any time after class.

In the Classroom

The course was taught in the department's multimedia classroom. A 486/66 computer running Microsoft NT Workstation© serves the classroom. Computer presentations were displayed to the class using a 48-inch monitor. The network connection allows access to resources on the department network, the college network, or any internet site. The classroom is also equipped with a white board and a transparency machine. Tables are used instead of desks to facilitate active participation groups. When the room is filled to capacity, three students may comfortably sit at one table.

Many of the lecture modules were prepared using Microsoft Powerpoint©. Lectures were augmented using transparencies of problems prepared with Mathcad©, transparencies of other supporting information, and "chalk and talk." Two field trips were taken to enhance understanding of lecture material. For one of the field trips (water treatment plant), a module with pictures and descriptions of the plant processes was developed. The module could be accessed from the web site during or outside class. Also being evaluated for use as study aids or classroom presentations are modules developed using the Academic version of Authorware©. One such module on air pollution was developed as part of a 1996-97 senior project.

Advantages and Disadvantages

While computer technology offers an engineering educator power and flexibility in making classroom presentations and disseminating information to students outside the classroom, there are some potential disadvantages that may need to be addressed to optimize teaching effectiveness. For example, although an electronic presentation offers a very efficient method of presenting material, it also enables a professor to move at a pace beyond the students' ability to absorb the material. I attempted to guard against this by pausing at critical slides to write on the board, ask questions, or relate stories that illustrated the concept.

By making the course notes available to students in advance of the class, students will ideally bring the notes to class and concentrate on taking selective notes of major concepts or filling in details not covered in the notes. Unfortunately, past experience with this type classroom presentation indicated to me that some students are less attentive in class once they have a set of notes in their hands. I attempted to offset this tendency somewhat by periodically emphasizing strategies for maximizing success in the classroom. However, the most effective technique that I found for helping students to focus in class was the active learning groups. These groups can help students to recall, think about, and talk about material that has been presented in the preceding lecture module in a way that is often enjoyable for them. Hence, although the groups take up valuable classroom time, electronic presentation and dissemination of notes can help to "buy back" some of that time, and the use of active learning groups can be effective in enhancing the learning process.

One alternative that I considered for making the notes available ahead of class was to present the material in class first, then make it available on the web site following the class. On a couple of occasions early in the semester when campus network printers were not working, I discovered that there were problems with this approach as well. When the students did not have the notes with them in the classroom, they seemed to focus their entire attention on transcribing notes rather than on understanding the concepts being presented. There were a number of requests to back up a slide to allow transcribing even though the same slide could be accessed later from the web site. If this alternative is used, it may be necessary to spend some class time (especially with younger students) helping students to learn to focus on major concepts while taking selective notes.

At The Citadel, class attendance is required, so there is generally no tendency to get the notes and skip the class. However, cadets are required to serve as guards at barracks or entrance gates several times a semester, which may result in missed classes. When this occurred, an individual could easily acquire the class notes (from a reliable source). Similarly, students could acquire notes when they missed class because of sickness. Nonetheless, it is important to both tell and demonstrate to students that there are things being presented and happening in class that they will miss if they

are not there and actively engaged. This would be especially important in classes where attendance is not required. One example of this is a graded exercise that is started (or even completed) in class by base groups.

It should be noted that although a considerable amount of time was required to place the course information on the web site, the amount of time needed for future offerings should be much less. Also, I was actually able to save some time that would normally have been spent on running copies and distributing them in class. Finally, I plan to eventually link the course web site with a number of other web sites around the country containing information on environmental engineering, so that students can readily access the wealth of information available to them on the internet.

Personal Classroom Observation

As background for my observations in the classroom, I (Fallon) would like to share some thoughts concerning the direction teaching appears to be taking. I have been in the academic business for over 15 years. During this period I have been fortunate to receive recognition for my efforts in teaching. This led me to believe that I was an effective teacher. However, for the last six years I have been undergoing a paradigm shift with regard to my concept of effective teaching. Originally, my approach to teaching was to lecture as if a student was a passive receptacle for me to fill up with knowledge. This is definitely not true! I now believe that the emphasis *should not be on my teaching but on the student's learning*. In the past, I measured my performance against the wrong criteria. I now believe that it is important to get the student actively involved during class time.

Over this six-year period I have tried to implement more active learning in the classroom. Non-scientific evidence has convinced me that introducing active learning as discussed in this paper and in the literature on engineering education will improve learning. For example, one evening in a mechanics of materials class, I assigned a problem to be done in teams. One student looked at me with obvious disappointment as she said something to this effect, "I was hoping that we would not do team work tonight for I am tired and do not want to think." The implications of this casual comment are revealing: active learning promotes thinking while traditional lecturing may not.

As the beginning of the term in which the new Introduction to Environmental Engineering course would be taught drew near, I was aware that a combination of techniques would be used to enhance the learning environment, including

- active learning techniques;
- computer presentations;
- use of the Internet for lecture notes; and
- stimulating interest through field trips.

Co-author Kenneth Brannan (who was teaching the class) and I agreed that it would be interesting for me to sit in on this course to observe the reaction of the students. Logistically, I sat in the far back of the class to ensure that I would not interfere with the interaction of students and teacher. This position also gave me a position to see the entire class in action.

The first thing I noticed was significant *student to student interaction* leading to an active and sometimes considerably noisy classroom. Students would not only discuss concepts in their assigned groups but also began discussion with members of other teams. From my vantage point the students appeared to be much more involved in the critical evaluation of concepts and problems than I have ever seen in a traditional lecture class. As the teacher moved from group to group, there appeared to be more professor/student interaction. The students seemed to feel freer to ask questions in their groups than in the traditional classroom format. These questions appeared to be thought-provoking and well-formulated. In fact, a number of times students asked questions concerning issues that went beyond the discussion in class; for example, some questions reflected interest in environmental issues in the local news. As he moved around the room, the professor could also challenge individual thoughts or get a student to think much more critically as the student expressed ideas during an exchange with the professor. Although this type of interaction occasionally appeared to slow the class, the pace during the presentation using slides of information was quicker than with a traditional lecture. However, since the notes were obtainable from the web site, the students appeared to have no problem keeping up. The added field trips and especially the timing of the trips with the classroom discussion added much relevance to the educational experience.

From my perspective, there were a few negatives. It was very apparent that to prepare a class using these techniques took considerably more time than it would have for lecturing. Sometimes the printing system in the computer laboratory could not meet the demands for lecture notes. Hence, some students would not have their notes before class. A number of times this was the fault of the students waiting until the last moment to get the notes. Finally, at times effort was required to get the students back on track after an active learning exercise in class. In other words, the students wanted to continue to talk (what I would consider a good problem!).

In summary, from all that I observed this is an excellent format for teaching a class. The students are more active and appeared to gain more from the classroom experience than the passive traditional lecture.

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