Experience with the Use of Interactive Classroom Technologies for the Implementation of Problem-Based, Peer-Interaction Learning Environment in Civil Engineering Materials

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Abstract

Are you a faculty member who is curious if the class is following what you are presenting? Have you ever been curious to know what the student in the third row is thinking while you are talking? Do you spend many sleepless nights wondering how you will increase class participation? This paper describes the implementation of an interactive classroom technology that was designed to address each of these questions, and to improve your students experience in the classroom.

This paper describes the experience of incorporating an interactive classroom response system in a required sophomore/junior course on Civil Engineering Materials. This course deals with cement, concrete, asphalt, and wood. Since this course is a required class with typically 70 to 100 students, it is often difficult to develop the type of personal interactions that you would expect from a smaller class. To overcome some of the limitations associated with the lack of participation that is typical in a large class, this course made use of a remote response (i.e., remote control) technology that enabled every student to participate and interact throughout the course of the lecture. In addition to encouraging nearly 100% participation and enabling nearly instant grading and attendance, the methodology developed enabled problem-based, peer-interactive learning during the large lecture format. This format enabled the students to work on practical problems by teaching one another, thereby reinforcing important class concepts.

This paper will describe: 1) the background of civil engineering materials classes at Purdue, 2) the motivation for investigating how to improve the learning experience in the materials courses, 3) the background of interactive classroom technology, 4) methods to incorporate the personal response devices in class, and 5) plans for future developments.

1. The Background of the Civil Engineering Materials Classes at Purdue

The School of Civil Engineering at Purdue University has long been dedicated to teaching students about engineering materials. This dedication began in 1883 with a laboratory for testing materials in the college of engineering [1]. In 1899, this lab was moved to the school of civil engineering and eventually became the foundation for CE 231 – Engineering Materials I and CE 331 – Engineering Materials II. While these courses were referred to as the "Busting Labs" at the turn of the century, since the 1960's these courses have strived to provide students with a fundamental understanding of the structure of materials, characterization of materials, and relationship between the properties and structure of materials. Over the last four decades, this methodology has become referred to as 'the material science approach'. The following section describes the content of these courses and provides some of the background that lead to the incorporation of the interactive teaching technology in CE 331 during the spring of 2005 [2].

Engineering Materials I (CE 231) is a required sophomore level course that is divided into three parts. The first part of the course begins by introducing concepts of mechanics including stress and strain. The materials response to stress are described including the concepts of 1) linearity and nonlinearity, 2) elasticity and inelasticity, and 3) brittle, quasi-brittle and plastic behavior. The second portion of the course strives to describe the structure of materials on an atomistic level including crystal structures, bonding, theoretical properties, and defects. Metallic alloys are discussed including basic concepts, strengthening mechanisms, and phase diagrams. The third portion of the course discusses the composition, manufacturing, and processing of metals, with a special emphasis on steel. Finally, multi-axial failure criteria and fatigue are discussed.

Engineering Materials II (CE 331) is a required sophomore/junior course on Civil Engineering Materials that deals primarily with aggregates, asphalt, cement, composites, concrete, fracture mechanics, soil, visco-elasticity, and wood. It should be noted that both courses (i.e., CE 231 and CE 331) are required of every civil engineering student at Purdue and students hoping to specialize in structures, transportation, geotechnical, and environmental branches of civil engineering heavily populate these courses. As such, students may not always be the most interested in the subject matter of the required materials courses when they arrive in the class. Further information on the content of CE 231 and CE 331 is available on line [3].

2. Motivation for Investigating Methods to Improve the Learning Experience

The motivation for investigating if teaching methods could be modified to improve instruction in the materials courses at Purdue began with an observation from the spring semester in 2000. It was the first time that the first author had taught the CE 231 course and was only the second semester that the first author had been teaching at the university level. In reviewing the performance of the students on the first two exams, an interesting observation became evident. A high proportion of students who performed very well on the first exam tended not to perform as well on the second exam, conversely a high proportion of students who performed very well on the second exam tended not to have performed well on the first exam. While it was initially thought that this observation might simply be explained by increased motivation of students who performed poorly on the first exam and relaxation by students who had performed well, there appeared to be additional commonalities between a student's performance on the exams and the student's branch of emphasis in civil engineering. It appeared that geotechnical and structural students tended to perform well on the first exam while environmental and transportation students tended to perform better on the second exam. This however would not be unexpected as the first portion of the course deals with mechanics topics that formulate the foundation for structural and geotechnical engineering and the second portion of the course deals with chemistry and conceptual discussions about the structure of materials which may be more familiar for environmental and transportation engineers.

During the spring and fall of 2001, similar observations were noted causing the first author to begin to question whether this trend was simply related to a student's interest or whether this may deal with how the materials are presented. For example, the lectures during the first portion of the course typically were conducted using the blackboard and equation-based problem solving. However, the lectures during the second portion of the course tend to be more conceptual in nature and were typically conducted using a slide/powerpoint format. Further, the first portion of the course contained a substantial amount of homework and lab problems involving equations and calculations while the second portion of the course contained more discussions and conceptual descriptions.

Based on these observations, the first author began to investigate how students learn from different lecture methods. One of the first writings that caused the author to think more about how lectures could be modified to address the needs of all students was based on the work of David Kolb in his learning styles approach [4]. It was observed that Kolb divided the learning process into a cycle where the student use an experience as the basis for reflection that is then distilled into concepts that are used by the student for the next experience [5]. In a review of the extensions to Kolb's ideas, Blackmore [6] suggested that as opposed to the cyclic learning process that Kolb proposed, many people prefer specific learning styles. This caused the first author to begin to wonder if the root of the observations from the CE 231 class may result from the way specific groups of students prefer to learn. It led the author to begin the process of trying to develop a wide range of classroom experiences and assignments that may fit the needs of a variety of students. As further information was reviewed however, some interesting observations were made along the way, causing the focus to shift more towards an interactive classroom approach as described in the following section.

Blackmore [6] described how Litzinger and Osif [7] developed a diagram (like Figure 1) to organize Kolb's learning styles and to identify how you may teach to target each of the learning styles. It was suggested that students learning styles fall into one of the four quadrants. As a result, the students tend to respond to different assignments and teaching styles differently. Cooper [8] suggested that engineers tend to be convergers who learn using Abstract Conceptualization (AC) and Active Experimentation (AE). Zanich [9] reported that convergers tend to like to learn through hypothetical-deductive reasoning, like specific examples, and like to work on problems with a single correct answer. This would be consistent with the first author's experience with many civil engineering students. In reviewing the instructional methods that work best for each learning style, Blackmore concluded that "above all, the instruction should be interactive not passive for convergers" [6].

While the first author has always tried to encourage class participation and interaction, the size of CE 231 and CE 331 (typically 70 to 100 students) can make this difficult to do. Further, class interaction only engages a small segment of the student population as the same students often volunteer answers while shyer students do not participate in the class discussions. Since students learn more effectively when they are actively engaged in learning, methods were investigated to make the classroom experience more interactive to improve the overall learning environment for all students. While some have suggested that the traditional Socratic method of questioning can maintain the students' interest and keep the class active [10], Rodell [11] reported that the use of the Socratic method can "discourage participation from many students, particularly women and minorities". The personal student response units (i.e., remote controls), as described in the following section, were found as one method that may be able to solve this problem by encouraging participation by all students [12]. After reading about the interesting approach of Mazur [13] in using an interactive classroom technology to teach core physics classes in Harvard, it was decided that during the spring of 2005 a similar approach would be used in one of the core materials courses at Purdue (Figure 2). The following section provides background on the equipment used in implementing the interactive classroom technology, the approach employed by Mazur, and the approach that was used in CE 331.

3. The Background on Interactive Classroom Technology Used in CE 331

The interactive classroom response system used in this course was produced by Hyper-Interactive Teaching Technologies (H-ITT) [12]. The system consisted of three main components: 1) a personal response keypad, 2) wall mounted receivers, and 3) software for acquisition and interpretation (Figure 3). The personal response keypad is similar to a remote control that the student purchases and brings to class (In comparison to the cost of textbooks, these keypads are fairly inexpensive after considering rebates from publishers, and can be used for several courses). Each keypad has a code so the student can be identified and their responses can be recorded. Two wall-mounted receivers were brought to class each day and attached to the wall using Ve1cro tape. The wall receivers were connected to a laptop that was equipped with the H-ITT software to record and analyze the response of the personal response devices. Using this system, all students could answer a multiple choice question in a matter of few seconds while the instructor could obtain a simultaneous measure of students understanding of the material being taught. The software provides a summary of each student's answer as well as the percentage of students who chose the right or any of the wrong answers (Figure 4).

In his book, Mazur [13] described a methodology in which he uses a similar personal response technology to enable peer-interactive learning in physics classes. He described how they incorporated a "convince your neighbors discussion" after the questions were initially answered, which resulted in a high degree of students obtaining the correct answer. Mazur explained how the conventional lecture could be modified to more of a discussion format and students can explain concepts to one another allowing them to both learn by teaching and learn through hearing the materials presented in more than one method. Mazur has developed a series of questions that can be used in physics classes.

Portions of the approach advocated by Mazur [13] were incorporated in the CE 331 class during the spring of 2005. During this semester, CE 331 met four times per week with two fifty-minute lectures, one fifty-minute lab preparation lecture, and a two-hour lab period (It should be noted that in addition to using the personal interactive devices, the fifty-minute lab preparation lecture to the entire class was introduced in this semester to shorten the lab period from three hours to two hours. This was done in an effort to provide students with an opportunity to hear about lab procedures few days in advance of performing the experiment and to help them bridge a link between the theory taught in class and experiment done in the lab, and appeared to be well received by the students.). The lecture section had eighty-five students enrolled while the laboratory sections had approximately 20-22 students in each section. The personal response devices were incorporated in the two fifty-minute lectures and the fifty-minute lab preparation lecture. The responses were only used for taking attendance during the spring of 2005, since the first author was initially concerned that cases may arise where students' responses may not be recorded. However, based on our experience during this semester, future use of the personal response pads will be for both attendance and correctness of the answers.

4. Methods to Incorporate the Personal Response Devices

Three different methods were used to incorporate the interactive technology in the classroom. The first approach was to use the personal response keypads to ask questions at the beginning of class. Specifically, this was used to try to get students to read and prepare for class. When students were polled, 85% preferred to take an extra credit quiz at the beginning of the class about the material in the textbook if the class lectures would be used to discuss more practice-oriented problems. This resulted in an environment were students were more likely to have read prior to class and to be prepared to think on their feet.

The second approach was to ask the students questions during the lecture that may require them to assemble concepts from the lecture or work in small groups through a problem to reason a solution. For example, in one class students were provided with the compressive strength of a concrete and asked to estimate the potential for shrinkage cracking. This required students to develop the equations that would be needed to predict the potential for cracking. Since these equations are not based on only compressive strength and require information on the tensile strength, elastic modulus, and shrinkage, it forced students to recall equations from the previous lectures that relate strength to other properties to estimate the material's shrinkage and stiffness. With this information, students could then use these values to compute the potential for cracking. The students could then answer the question using their personal response keypads.

The third approach used in CE 331 was more along the lines of the approach advocated by Mazur [13]. This was to use the response system to provide a problem-based, peer-interaction learning environment in the classroom. Some of the CE 331 classes would begin by asking a practical question to get the students 'thinking about a problem'. For example, the portion of the class dealing with concrete technology began by asking students to review a series of concrete mixture designs and to predict the mixtures that would have the highest strength, highest durability, and lowest cost. This enabled students to use their 'natural instincts' and generally between 20 and 35% of the class predicted the correct answer at the beginning of the class. This question was effective in beginning the process of making the students think about the practical applications of that day's lecture and it kept them interested in the lecture as they were searching for concepts that they could apply to the question. The students were then asked the same questions at the end of the lecture at which point the percentage of correct answers were usually increased to about 65 to 70%. Then the students were allowed to consult with one another giving them the opportunity to develop an argument for their position and convince each other of their reasoning. The question was then asked for the third time and this time the great majority of class (above 90%) could choose the correct answer (Figure 5 provides an illustration of this approach).

In addition to providing a peer-interactive environment, this method enabled the instructors to determine immediately at the end of each class if the students captured the main concepts from the lecture. While many of the concepts can be easily grasped resulting in a high percentage of the correct answers at the third time, there were certain concepts that were not clear even at this time. For example, one particular question on the water-to-cement ratio resulted in only about 60% of the students answering correctly at the end of the lecture providing an opportunity for any misunderstandings to be clarified before the students left the lecture.

5. Summary and Plans for Future Development

The approach used in the CE 331 class during the spring of 2005 was an initial attempt to use the personal response keypad system to improve the learning environment in Civil Engineering materials classes at Purdue. It can be noticed that this paper describes a work in progress and as such, it is anticipated that modifications will be made in future use of this method. Overall, the implementation of the personal keypad response system was quite positive, as it 1) enabled higher student participation during the class, 2) provided an opportunity to encourage students to read on their own, 3) provided an interactive classroom environment in which students could discuss with one another and try to justify their position and convince each other of their reasoning, and 4) gave the instructors an instantaneous feedback of the students understanding of the material and an opportunity to clarify any misunderstandings before the students left the lecture. Nevertheless, a more detailed outcomes assessment of the method needs to be conducted in future courses.

The students' response in general was quite positive. Students appreciated that more material was covered in the class since less time was spent covering the materials that could be learned from the reading assignments. It should be noted, however, that the students did mention that there was more material to consider in preparing for the exams. By having the students covering some material through their reading assignments before the lectures, the class discussions were also shifted from a more classic lecture to a discussion where the students were more active in the entire process. It was also interesting to note that the students who came to office hours to comment on their appreciation for the system were students who typically had grades in the lower ranges. The problem-based, peer-interaction learning environment was also seen to be very positive as it increased student interaction and learning, especially from students who may not be willing to speak up in a more conventional lecture.

From an instructor's perspective, the technology resulted in substantial reduction in the time spent on menial tasks of teaching including the grading of attendance quizzes and quizzes based on the reading assignments. Each question could be answered in about 30 seconds; however a 10 to 15 second break was required between questions from a practical point to enable the computer to be reset and to enable the students to make sure that they answered the correct question. The use of questions during the lecture enabled the students to remain engaged in the class.

The first author plans to use the personal response keypad system in the fall of 2005 for CE 231. This course offers the potential to begin to investigate how peer-interaction may be used to allow students with different learning skills to help each other with the mechanics concepts as well as the fundamental theoretical concepts. Specific attention will be paid to understand whether the disparity in learning styles can be bridged between students interested in mechanics and students interested in the more chemical and theoretical aspects of materials. An increased use of student surveys will be conducted. The course will shift from the use of the H-ITT personal response system to the E-Instruction system simply because these tools have been implemented campus-wide at Purdue and it will enable the students to use the remote controls in more than one class, thereby making them more economic for students.

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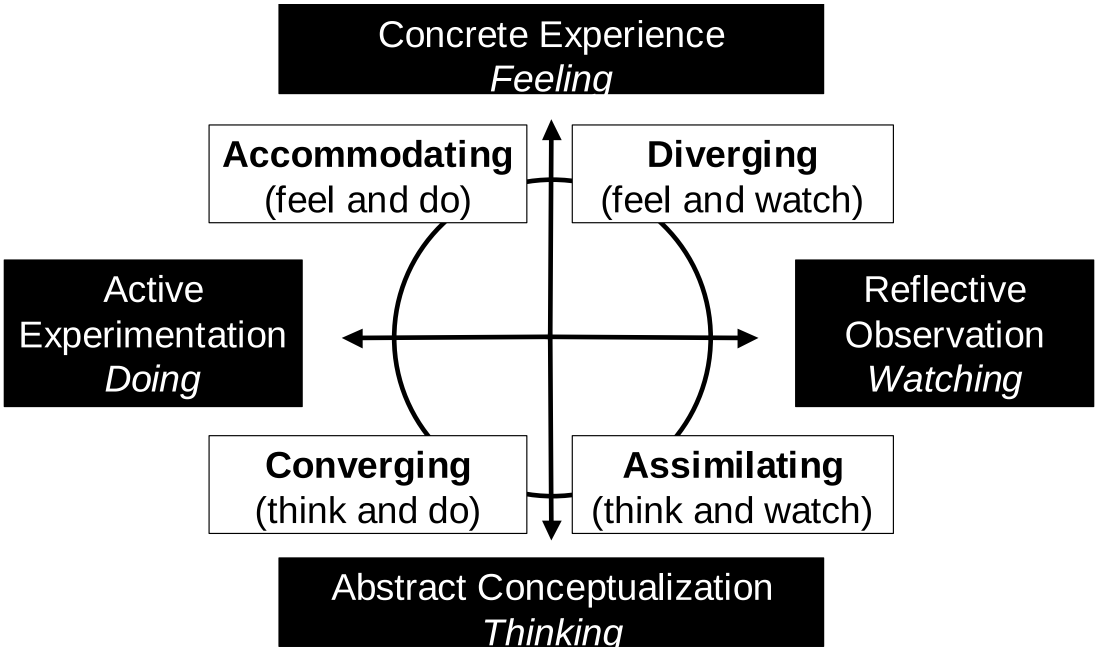
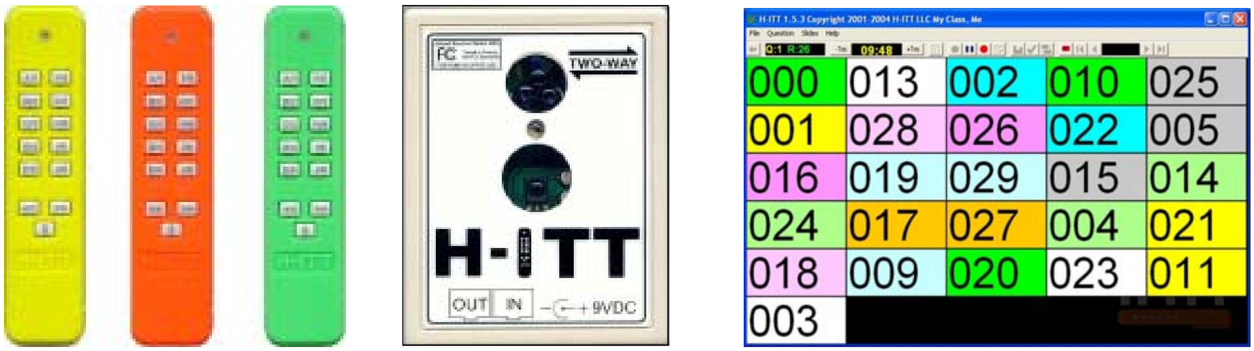


Figure 1: A graphical illustration of the learning styles advocated by Blackmore [6]

Figure 2: An example of the personal response system being used in CE 331 – Engineering Materials II during the spring of 2005



(a) (b) (c)

Figure 3: Typical equipment used for the interactive classroom: a) personal response keypads, b) wall mounted receivers, and c) software for response acquisition and interpretation [12]

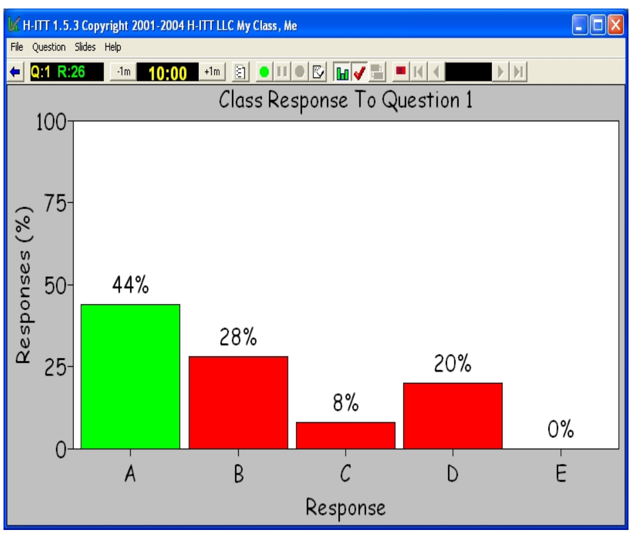


Figure 4: Bar chart showing the percentage of students who chose the right (A) or the wrong (B-E) answers to a particular question [12]

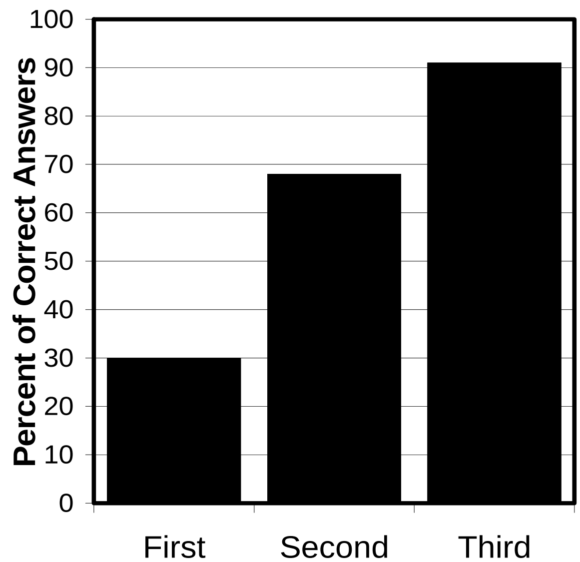


Figure 5: Typical response to the questions asked at the beginning of the class (First) at the end of the class (Second), and after peer interaction (Third)