Implementing Active, Cooperative and Team-Based Learning in a Probability Course for Engineers

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Abstract - Continuous quality improvement evaluation efforts revealed that student performance in our probability course, EE 3384: Probabilistic Methods in Engineering and Science had been on the decline for the past several years. Several hypotheses have been proposed by the faculty to explain the performance decline in this required course for electrical engineering and computer science majors. In order to raise student performance in the course, it was essential to examine the manner in which the course was being taught. Prior to the Fall Semester of 2005, the course was taught using a traditional lecture format. An initial move was made for the Fall Semester of 2005 to implement active and cooperative learning strategies. Subsequently, elements of team-based learning were implemented in the Spring Semester of 2006. This paper addresses the implementation of these learning strategies in the course. Preliminary results suggest an increase in student performance and an improvement in students’ attitudes toward the course.

Index Terms – Active learning, cooperative learning, team-based learning, probability

INTRODUCTION

This paper discusses the implementation of team-based learning in an upper-division probability course for electrical engineering and computer science students at The University of Texas at El Paso (UTEP). Ongoing assessment of educational outcomes for the course indicated that student performance had been on the decline for the past few years. Several hypotheses have been advanced by the faculty to explain the performance decline in this required course for electrical engineering and computer science majors.

In an attempt to understand better the reason for the decline in student performance, faculty examined not only topics and content of the course, but also the manner in which the course was being taught. It was the belief of several faculty members that student performance could be increased by the introduction of new learning strategies. It is important to note that prior to the Fall Semester of 2005, the course was taught using a traditional lecture format. During the Fall Semester of 2005, elements of active and cooperative learning [1] were introduced. In the following semester, team-based learning [2] strategies were incorporated in the course.

This paper addresses the implementation of active, cooperative and team-based learning strategies in the course. It describes the techniques that have been deployed and presents preliminary results of student performance as it relates to the educational outcomes of the course.

COURSE DESCRIPTION

EE 3384 (Probabilistic Methods in Engineering and Science) is an upper division course for electrical engineering and computer science majors. It is a required course in the curricula for both fields. The course is an introduction to probability that addresses discrete and continuous random variables, various distribution functions, moments, statistical independence and independence, and elementary statistical methods. Students are required to apply the principles of the course through problem assignments and other applications. An emphasis is placed on problems and applications drawn from engineering and science. All students enrolled in the course have satisfied the prerequisite of having completed the 3-semester Calculus sequence. Approximately 200 students enroll the course each academic year and section sizes range from 40 to 80 students.

Educational Objectives

The educational objectives of the course are stated in the course syllabus and are as follows.
1. Solve basic counting problems involving permutations and combinations of equally-likely events.
2. Use elements of set theory and axioms of probability to determine the probability of complex events, and apply Bayes Theorem to the solution of conditional probability problems.
3. Solve problems involving independent events and independent random variables.
4. Determine marginal and joint cumulative distribution functions, probability mass functions and probability density functions and use them to compute various expected values of discrete and continuous random variables.
5. Solve problems involving Gaussian, uniform, exponential, binomial, and Poisson random variables.
6. Compute expected values of sums of random variables and the covariance and correlation of pairs of random variables.
7. Use the Central Limit Theorem, significance tests and hypothesis tests in introductory statistics problems.

**General Observations on Student Performance**

Student performance in EE 3384 has been a topic of discussion among the ECE faculty for a number of years. Generally speaking, students have some of the same problems and challenges with the course that students historically experience in other courses in the electrical engineering and computer science curricula at UTEP. Specifically, a majority of students are able to answer exam questions covering basic principles when the questions posed are similar to examples worked by the instructor in class. However, a much smaller percentage of students are able to answer correctly exam questions that are significantly different from examples presented by the instructor in class. Because many students often fail to spend an appropriate amount of time doing assigned homework, a large percentage of students cannot answer correctly exam questions that are slight variations on assigned homework problems. Additionally, students struggle when they are presented with exam questions that require that they combine two principles to create a third principle. It would appear that students spend much of their time reviewing for exams by committing to memory problem solutions presented in class by the instructor.

Despite the efforts of the faculty to select appropriate texts for the course, it appears that students spend little time reading the text. They thus gain little from the reading assignments and this creates a number of learning obstacles for students. To begin, students come unprepared to class and thus do not benefit as much as they should from the lecture periods. Instead of using lecture periods to refine their understanding of course principles and their applications, many students experience the topics for the first time through the instructor’s lecture. During lectures, many students spend much of the lecture period furiously copying notes from the lecture, despite the fact that the definitions and theorems presented in the lecture are drawn directly from the text. This gives students little time to reflect on the principles and their application.

Student lack of preparedness for class appears to be a significant factor that discourages learning. In the Spring Semester of 2005, an instructor for the course wished to gain a better understanding of student preparedness by administering short quizzes at the start of class periods. These quizzes were not designed to be difficult. The quizzes were unannounced but did cover topics presented in the previous lecture.

Student performance on quizzes bore out the fact that a large percentage of students simply did not come to class prepared to learn. It should be noted that the questions comprising Quizzes 1-4 were drawn directly from the 5th and 6th grade Texas Assessment of Knowledge and Skills Test Preparation Guide. With even a minimal level of preparation, a university student could have answered correctly the problems on Quizzes 1-4.

### Changing the Teaching and Learning Approach for the Course

In an effort to address the perceived problems inherent in the course, program faculty began to examine the manner in which the course was being taught. The conclusion of the faculty was to move away from the traditional lecture format toward an approach that would allow students to learn more effectively. It was deemed critical that modifications be made that would introduce activities that would engage students in doing something beyond merely listening to a lecture and taking notes to help them learn and apply course material. Involving students in a manner that would involve them more in talking and listening to each other was considered an important objective on any modification in the way the course was to be taught. Another objective was to teach the course in a manner that would involve groups of students working together on structured assignments that would help assure positive interdependence, individual accountability, improvement in interpersonal skills, and regular self-assessment of group dynamics.

During the Fall Semester of 2005, elements of active and cooperative learning were infused into the course to address these objectives. Cooperative learning [1] is a topic that has received considerable attention in the literature. As a first step toward implementing cooperative learning for the Fall Semester of 2005, a special class room was assigned for the course that contained ten circular tables. The class was divided into groups of four students, each with an assigned table.

A number of techniques were employed during the semester. Many of these techniques were drawn upon those presented in a workshop presented by Felder and Brent [3].

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**Session T4B**

**Table I: QUIZ RESULTS FOR SPRING SEMESTER 2005**

<table>
<thead>
<tr>
<th>Quiz</th>
<th>Course Objective</th>
<th>Percentage of Correct Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>39%</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>61%</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
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<tr>
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<td>92%</td>
</tr>
<tr>
<td>13</td>
<td>5</td>
<td>11%</td>
</tr>
<tr>
<td>14</td>
<td>7</td>
<td>52%</td>
</tr>
</tbody>
</table>

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**San Juan, PR**

9th International Conference on Engineering Education

T4B-9
These included the use of the minute paper [4], problem-based learning [5], group homework, and formal peer feedback. The introduction of these techniques had a salutary effect on classroom dynamics. Students became more active in class. There was a marked increase in interaction between the instructor and the students. Questions from the students were more abundant and dialogue improved. Though all of these developments were positive, examination of student performance as measured by the educational objectives of the course were still lacking. Once again, the major weakness associated with student performance appeared to be the lack of student preparedness for class. As a consequence, the faculty decided to introduce elements of team-based learning for the Spring Semester of 2006. Much of what was implemented in terms of team-based learning was gained through a workshop held by Michaelsen [6].

TEAM-BASED LEARNING

Fink defines team-based learning as “a particular instructional strategy that is designed to (a) support the development of high performance learning teams and (b) provide opportunities for these teams to engage in significant learning tasks.”[7] Team-based learning is an instructional strategy rather than a series of independent group activities. Under team-based learning, group activities are combined and sequenced in a manner that seeks to transform small groups into powerful learning teams. It involves the restructuring of the course to accommodate the implementation of the learning activities that are key features of the approach. The team-based learning activities which have been implemented in the EE 3384 course are described in the following paragraphs.

To begin, the course was segmented into seven units focused on the major topics of the course. These units are presented below.

- Unit #1 Basic Principles: Set Theory, Probability Axioms, Conditional Probability, and Law of Total Probability
- Unit #2 Independence, Sampling and Enumeration: Independence, Sequential Experiments, Tree Diagrams Counting Methods, Sampling with Replacement, Sampling without Replacement, Permutations, Combinations, Independent Trials, and Reliability Problems
- Unit #4 Continuous Random Variables: Cumulative Distribution Function of a Continuous Random Variable, Probability Density Function, Expected Value, Families of Continuous Random Variables, and Gaussian Random Variables
- Unit #6 Sums of Random Variables: Expected Values of Sums, Random Sums of Independent Random Variables, Central Limit Theorem, Applications of the Central Limit Theorem, and Chernoff Bound
- Unit #7 Parameter Estimation Using the Sample Mean: Sample Mean, Expected Value of Sample Mean, Variance of Sample Mean, Markov Inequality, Chebyshev Inequality, Point Estimate of Model Parameters, Point Estimates of the Expected Value, Weak Law of Large Numbers, Point Estimates of the Variance, Sample Variance, and Confidence Intervals

Each unit represents approximately two weeks of work during a 14 week semester. The team-based learning strategy is based upon a three-step sequence: preparation, application and assessment.

**Preparation Phase**

During the preparation phase, students are assigned to read the entirety of the material associated with the unit. This reading takes place outside of class. Rather than to develop an in-depth mastery of the material, the goal here is for students to obtain a good introduction to the topics of the unit and a familiarity with its terminology. A Readiness Assessment Process [7] is initiated during the first class period associated with the unit. Here it is assumed that all students have read the unit for basic understanding. The primary purpose of the Readiness Assessment Phase is to ensure that students are prepared to learn how to apply material from the reading to physical problems and to insure individual and team responsibility for understanding the material.

The Readiness Assessment Phase begins when each student is administered a short multiple-choice Readiness Assessment Test. The Readiness Assessment Test is first taken individually. Upon completion, the Readiness Assessment Test is turned in for grading. This step takes approximately 15 minutes of class time. Once all students within a team have completed their individual Readiness Assessment Tests, the members take the same exam only this time as a team. The grades from both the “team” and the “individual” Readiness Assessment Tests count toward a part of the course grade. Sufficient class time is allowed for the “team” Readiness Assessment Test to allow students to share ideas on the questions and to develop consensus regarding the proper answer to each question.

Special forms known as Immediate Feedback and Assessment Test (IF-AT) [8] forms are used for the Team Readiness Assessment Tests. IF-AT forms allow students to answer by scratching off their responses, similar to the way people scratch off lottery tickets. If a star appears where the students answer on the form, the students know that their response was correct. If instead the students do not see a star
where they scratched, they may continue to scratch other responses until the correct answer is revealed. Of course, each successive scratch lowers the team’s grade on their Readiness Assessment Test. Each question has 4 possible answers (a) – (d). If the team scratches the proper answer on the first try, the team earns 4 points. If the team takes two tries, then it earns 2 points. A correct answer after 3 scratches receives 1 point. Otherwise, no points are earned. This scoring system in some ways compensates for the lack of “partial credit” which is a common criticism often associated with multiple-choice tests. An important characteristic of the Readiness Assessment Phase is that it provides immediate feedback to the students as to their level of preparation to begin applying the concepts of the unit.

The results of the Readiness Assessment Tests are easily obtained by the instructor because the feedback is immediately provided through the use of the IF-AT instrument. Based upon individual and team results on the Readiness Assessment Tests, the instructor can then begin to offer insight and additional comments that he or she feels are necessary to enable students to gain an understanding of the key elements of the unit. Delaying any lecturing until after the results of the Readiness Assessment Tests are obtained enables the instructor to focus on those topics that students were not able to understand on their own. This makes for a more efficient use of valuable class time. It also serves to engage students more in what the instructor has to say in that the instructor focuses on the topics most commonly missed on the Readiness Assessment Tests. This creates a classroom environment that is more energized and more focused on learning than what is typically experienced using a standard lecture format approach.

**Application Phase**

By the end of the preparation phase, students should have a basic level of understanding of the important topics of the unit. Next, the application phase of the learning strategy begins. In this phase, students are taught to apply the basic concepts in the solution of engineering problems. This is accomplished by having students work together with their team mates to solve problems of increasing levels of difficulty and complexity over the next several class periods. The instructor works as a guide through the team exercises by providing insight into the solution of problems and soliciting problem responses from the various teams. The role of the instructor during the application phase is to assist the teams in how to apply the material and to assist the students in becoming more cohesive as a learning team.

**Assessment Phase**

After students have had practice applying the topics of the unit, they then enter the final phase of the team-based learning strategy, assessment. At this point, students are given an exam on the unit which builds upon the types of problem solving techniques that the students have mastered during the application phase of the process. In the probability course under consideration, the first assessment exam was taken by each team, while the second assessment exam was administered individually. This process of alternating between team and individual exams was repeated throughout the semester and culminated with the Final Exam which was taken individually.

Once the process of preparation, application, and assessment was conducted for the first unit, the process would be repeated for the remaining units of the course. This interdependent sequencing of the preparation, application and assessment processes is what provides the basic learning strategy behind team-based learning. Over the course of the semester, students are trained in the process. It is hoped that students would gain an appreciation for the effectiveness of the process and to apply its reliance upon preparedness and application toward their study of other courses.

**Comparison between Cooperative and Team-Based Learning**

Both cooperative learning and team-based learning have been applied in the context of seeking to improve student comprehension and learning at the university level. Both have demonstrated positive results that have been widely documented. Both approaches make use of small groups of students to achieve their desired results. The primary difference between the two lies in the time scale that each approach uses and in the degree of integration that they are striving for. Cooperative learning utilizes small groups of students as a teaching technique that is applied in a series of independent learning activities. Here, each learning activity seeks to accomplish a specific learning objective. In contrast, team-based learning views small groups as a basis for a semester-long instructional strategy in which a sequence of small group activities is designed and linked to accomplish two primary purposes: deepening student learning and enhancing team development.

Other differences exist between the two approaches. With team-based learning, groups are established for the duration of the course. This is not a requirement for cooperative learning. In cooperative learning, students utilize assigned roles in the preparation of assignments. This requirement does not exist in team-based learning. Whereas cooperative learning requires that instructors spend class time teaching and analyzing group process skills, this is not necessary in team-based learning. Whereas the grading of team work is critical in team-based learning, group work may or may not be graded in cooperative learning. With team-based learning, prompt feedback on individual and team work is a critical element. This is not always the case with cooperative learning.

**COURSE ASSESSMENT**

The BSEE and BSCS degrees are accredited by the Accreditation Board for Engineering and Technology and the Computer Science Accreditation Board respectively. As part
of the Continuous Quality Improvement component ongoing accreditation efforts, the course is evaluated on a regular basis.

The primary method of assessing student performance in EE 3384 is through regular examinations and the final examination. Students who earn at least 70% of the points on exam questions for a particular educational objective are considered by the ECE faculty as having shown competency in the objective. Table II displays assessment results for the Fall 2002, Spring 2004, Spring 2005, Fall 2005 and Spring 2006 Semesters. It should be noted that the team-based learning strategy presented earlier in this paper was employed during the Spring 2006 Semester.

### Table II

<table>
<thead>
<tr>
<th>Educational Outcome</th>
<th>Fall 2002</th>
<th>Spring 2004</th>
<th>Spring 2005</th>
<th>Fall 2005</th>
<th>Spring 2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>88%</td>
<td>83%</td>
<td>50%</td>
<td>57%</td>
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<tr>
<td>2</td>
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<tr>
<td>3</td>
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</tr>
<tr>
<td>4</td>
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<tr>
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<td>6</td>
<td>43%</td>
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<tr>
<td>7</td>
<td>41%</td>
<td>14%</td>
<td>N/A</td>
<td>64%</td>
<td>92%</td>
</tr>
</tbody>
</table>

As part of its ongoing ABET accreditation activity, the ECE faculty established a performance goal a minimum of 70% of the students should show competency in each of the eight educational objectives. Observation of the data of Table II clearly indicates that this performance goal was not being met in most cases for the Fall 2002, Spring 2004, Spring 2005, and Fall 2005 Semesters.

The results obtained for the Spring Semester of 2006 which are presented in far right column of Table II are quite encouraging. The percentage of students who were able to show competency for each objective is clearly much higher than the percentages obtained in the four previous semesters included in the study. We attribute much of this improvement to the institution of team-based learning.

### CONCLUSIONS AND FUTURE WORK

The preliminary results obtained through the assessment of student performance clearly indicates that students perform better when team-based learning is employed in the teaching of the EE 3384 course at UTEP. The success that this learning strategy has demonstrated in this probability course suggests that perhaps student performance can be improved by instituting team-based learning in other courses. It is believed that this is especially true for courses where there is an emphasis on mathematical problem solving and engineering applications.

It is our belief that actively engaging students in their own educational growth can prove quite positive. Additionally, students gain other important career and life skills through team-based learning. In addition understanding of the technical aspects of the course, students also are allowed to develop their communication skills, interpersonal skills, teamwork skills, and organizational skills. Because these skills are viewed as important to future employers, students should be better prepared to enter the professional workplace.

### REFERENCES


