Work In Progress - Implementing and Refining Project-Based Learning for Annual Classes With Diverse Student Population

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Abstract - **Baker College of Flint offers an ABET-accredited BS Mechanical Engineering program, with classes held mainly in the evenings. The ME105 Introduction to Engineering and Design course is usually taken at the beginning of sophomore year, after math prerequisites. The student population is approximately twenty five percent female to seventy five percent male and seventy five percent white, twenty percent black, five percent Hispanic.**
In Fall 2007, 2008, and 2009 terms projects have been implemented as a part of the coursework. In 2007 students were allowed to choose their own projects and follow a standard set of design development steps to complete either a finalized design or a simple build project. In 2008 two design experiences were assigned – a paper bridge to be tested with weights during the fifth week and another paper bridge with tighter constraints to be tested at the end of the tenth week.
In 2009 two bridge projects were done along with an egg-drop test. The goal of these build-and-test projects is to teach the students about different aspects of engineering and design – meeting constraints with limited time, budget and materials.
From this three years of experience with the projects the performance of students does not reflect that any demographic of student performs better.

BAKER COLLEGE

The Baker College System is made up of thirteen campuses around Michigan, with a total system population of thirty thousand students.
The college was founded in 1911 primarily as a business college and now focuses on business, health sciences, teacher preparation, and technology. The Flint campus offers an ABET-accredited Bachelor's of Science degree in Mechanical Engineering, along with a non-accredited Associate's degree in Mechanical Technology. ABET accreditation was first obtained in 2003.
Baker College is a 'right to try' school meaning that anyone with a high school diploma or equivalent can enroll at the college. The student population ranges from eighteen year olds just out of high school to students in their forties or fifties starting a second career. Demographically the Mechanical Engineering program consists of approximately seventy-five percent male students and seventy-five percent white, twenty percent black, and five percent Hispanic students.

THE COURSE

ME105 Introduction to Engineering and Design is a course that is required for students enrolled in the Industrial Engineering bachelor's degree and the Mechanical Engineering bachelor's or associate degree. The course is offered once each year in the Fall term, with a prerequisite of MTH124 Trigonometry.
Many students have taken the math prerequisite in high school and take ME105 in their first year of classes while others require additional math classes and take ME105 at the beginning of their second year. The Introduction to Engineering course is designed to teach students about the methods and processes used by engineers – a survey class that is heavily involved in calculations and design problems.
The class runs on Wednesday evenings from 6:00-9:40pm, for ten weeks in the Fall term. In 2009 the course age ranged from eighteen to forty-five, some students having no engineering experience from high school and some students having worked in the industry for twenty years and finishing their education.
The challenge is always to teach a class that will have design problems to complete, a hands-on project that can be built away from class and tested, several homework assignments that will stress the engineering problem-solving and presentation method, communication and teamwork in a diverse population.
The class is made up of a mix of attention spans and experience in addition to demographics. An engineer analyzes, solves, designs, and communicates – those are the four main functions that are discussed the first week of the course. Communication can never be stressed enough because communication needs to be done not just to other technical people but also has to be done in methods that non-technical people can process.
Lectures and homework cover the engineering problem solving process, dimensional analysis to convert units, the principles of energy, material properties, and the various

disciplines of engineering. The concepts of simulation, optimization, problem-solving and innovation are covered in the design projects.

2007 PROJECTS

In 2007 the design projects were done in teams of between two and four students. Students were allowed to design any project that they found interesting, with the option to build a proof-of-concept model or finalize a design using commercially available CAD software. This approach worked in the sense that students all worked on something that interested them but there was no cohesive idea to all of the projects. Some students built trebuchets, others designed a bike rack, and another team designed a bridge using several truss designs to see which would be the strongest.

When starting the project teams no requirements for team make-up were given – instead of students grouping themselves together according to age, sex or race the students grouped according to year. Students familiar with each other from previous classes joined into groups and the split was more first-year students and second-year students. The quality of the projects was also uniform – students who worked hard and applied themselves were able to apply the engineering principles to their designs and students who did the least amount of work required to finish had projects that reflected that level of commitment.

2008 PROJECTS

In 2008 the project was changed – students individually built paper bridges to test during the fifth week, and students were grouped in fours for an aggregate score. Grouping four scores together is intended to encourage collaboration between students so that best practices and lessons learned. Constraints for the fifth week were that the bridges could be made out of a maximum of twenty sheets of paper, had to be at least three inches tall and span at least a six inch gap, using any amount of glue.

The first bridge test fifth week was done in the classroom using disc weights from the fitness center. This method proved to be difficult to control and not repeatable as a testing method. Some students had bridges that held the maximum weight of two hundred seventy pounds and some bridges held much lower weights before yielding. The discussion after the bridge testing focused on the innovations that some students had used, and which practices yielded the best results. Some students used cardstock because the constraints did not disallow cardstock. Some students took their bridges and used an oven to cure their glue for a stronger bridge. Students rolled paper tightly around pencils and pens to create stick configurations, or folded them in small blocks of fan configurations. Finally, some students used colored paper for aesthetics. Some of these techniques – chiefly stronger paper and curing the glue – made a noticeable difference in bridge performance. Next the teammates discussed the projects in their small groups with the task of finding best practices and designing a test method for the next bridge testing that would happen in the tenth week of the course. During the ninth week of classes each group presented their ideas for testing the bridges and the class voted on the best idea – the idea of using the tensile machine won out over the other groups' design. Because the assignment for the final bridge project was handed out in sixth week, some students had already started their construction or finished their construction, and finding out the testing method caused a few designs to be reconfigured before testing.

Constraints for the final project were that the bridges could not use more than fifteen sheets of paper, the paper could not be thicker than 100 lb cardstock, no more than one two-ounce bottle of Elmer's glue or equivalent could be used in construction, and the bridge had to be at least three inches tall while spanning a gap of eight inches. These constraints are intended to cause the students to reassess their first design while trying to optimize the weight that can be held by the bridge. Construction methods, gluing methods, truss configurations and best practices all factor in to the students final design. During the final testing in 2008 it was obvious that several students were influenced by what others had done in the fifth week testing, and that the competition fueled many new designs and more efforts.

Performance was not tied to any demographic – students fresh out of high school performed just as well as students who were in their forties, and white and black students performed around the same average. The students who looked like they had put a great deal of thought and effort into the assignment performed the best. Students on the bottom end looked as though their projects did not have the benefit of heavy amounts of effort and planning – some students admitted that they had started the project that afternoon despite knowing about the project for three weeks.

2009 PROJECTS

The Fall 2009 course included design projects where students broke into teams of three or four for an hour and brainstormed a fast sketch design on specific problems – designing a Chinese dragon float for a class of preschoolers, designing a shampoo bottle holder for a small shower, and designing a method of testing bridges for the course.

Bridge design testing was done again in the fifth and tenth weeks, and an egg dropping test was done in the eighth week of the course. The egg drop was intended to use five pieces of paper and drop an egg from ten feet several

times – the purpose of this one-week project was to force the students to make prototypes and test their ideas outside of the classroom so that the egg drop testing in class would be as successful as possible. The egg drop testing was enjoyed by the students but didn't fit into the flow of the course as intended. The egg drop test will probably not be performed again in 2010.

More discussion of bridges and trusses was done during the lectures in the 2009 courses. The West Point Bridge Design competition software was used in an early lecture about simulation, to stress to the students that different truss configurations can produce drastically different results. The simulation software also illustrates that changing materials and beam thicknesses can make big differences in the strength of a bridge. Another lecture centers around trusses, truss designs and very basic truss analysis. Because students need to have completed trigonometry before taking the ME105 course everyone has at least a basic understanding of sine and cosine, and can use that knowledge to do a basic truss problem and see the method of transforming forces using sine and cosine. Students that are mechanical engineers, both bachelors and associates, and industrial engineers will have to take ME201 Statics course after completion of the first calculus class. Statics is one of the courses that keeps students from moving on to higher level mechanics courses so giving the students a jump on truss analysis is useful for their engineering student careers.

The criteria for the fifth week midterm bridge test were that only twenty sheets of paper could be used, as much glue as needed for the project, and a six inch span. Because of scheduling issues with the tensile machine and other courses tensile machine was not available for us during the Fall 2009 term. Again this caused some students to reconfigure their bridge designs, because they were expecting to use the tensile machine which pushes up from the bottom as opposed to free weights pushing down from the top.

As an alternate testing method the bridges, both fifth week and tenth week, were tested in the fitness center using a weight bar and placing disc weights on the end of the weight bar. During fifth week books were placed on a table to act as spacers and the bridges were tested, and weights were placed on the bar in increments of twenty, thirty, eighty or ninety pounds. Students were again broken into teams and a group of four students were averaged for a team score that was weighted against other team scores. This was intended to force the students to exchange ideas and also to bring the scores to a median level. Because of the smaller number of students in our program and the rotation of classes between different years of student often overlaps, many of the students in the 2009 class already knew about the bridge testing projects from students in the previous year. Many students had ideas based on the previous year's designs, and this served as a discussion point to once again stress the fact that lessons learned from one population of people can be applied to a new set of people, with the intended result to be improvement over time. For the tenth week testing the weights in the fitness center were used again, and grading was done on an individual basis. Constraints were again tightened so that students could use a minimum of fifteen sheets of paper, no more than one bottle of glue, and the span was opened to eight inches. In addition it was required that each bridge have some method of indentation so that the weight bar could rest in the indent and be tested – during the fifth week some bridges slipped due to a flat surface and the contact with a round weigh bar. A rough frame was built using two by fours so that the testing method would be consistent for each bridge.

Fifty percent of the grading should have been easy for every student to achieve – the bridge needed to fit in the size window and not use more than fifteen sheets of paper. The other fifty percent of the grade was based on performance: zero to ninety pounds held gave a grade of seventy percent, ninety to one hundred eighty pounds gave a grade of eighty percent, one hundred eighty to two hundred seventy pounds held gave a grade of ninety percent, and more than two hundred seventy pounds gave a grade of one hundred percent. Two forty five pound weights were placed on the weight bar, one on each side of the weight machine, by two strong students to achieve the ninety pound increments.

This testing yielded much lower results than the fifth week testing and a majority of the students received a seventy percent for their final bridge testing grade. The tighter constraints definitely make the bridge design more difficult but adding the weights in ninety pound increments also seemed to hurt the performance. Two students placed the weights on the weight bar for all of the bridges except their own, so the testing method was consistent but many students realized that putting weights on very slowly would cause less stress on a bridge than placing weights on the bar quickly. A wide range of designs and implementations still existed among the students and a wide range of effort was also evident. There was no obvious correlation between bridge testing scores and students with or without experience in the engineering field, nor along any other demographic.

2010 AND FUTURE PROJECTS

The projects done in the previous three years are mostly an attempt to capture the interest of a diverse group of students while teaching them the principles of simulation, optimization, analysis and design. The motivation for these projects comes from trying to emulate experiences in classes from the author's college experience, and instilling a sense of competition with cooperation in the students where every student can help each other to get a better grade or a more successful experience.

When constraints say that students can use twenty sheets of paper it is always assumed that students will adhere to

the honor system and not intentionally use more than the stated limit. For the 2010 class a more structured project-based learning approach will be used. The framework of the Fall 2010 class will be done in the summer of 2010.

WORK IN PROGRESS CONCLUSIONS

After running the course for three years with the same project used in the second and third years, only one trend has emerged. Regardless of sex, race or age students seem to perform at the same level. Regardless of how a student has performed in previous classes or the instructor's perception of a student and his/her ability, the performance on these projects has been a project of the effort that the student puts into the project during their ten week term.

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