AC 2007-1531: PREPARING FRESHMEN FOR FUTURE ENERGY ISSUES

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Preparing Freshmen for Future Energy Issues

Abstract

In recent years, the University of Maryland, Baltimore County (UMBC) has revised its Introductory Engineering Design Course from a traditional lecture and design on paper course to an active learning environment featuring a variety of hands on activities and project based learning. Each week, students attend not only lectures with a university professor but also a hands-on discussion section led by a specifically selected teaching fellow (TF) whom has recently completed similar coursework. During the discussion sections, students are grouped into diverse, interdisciplinary, and academically-balanced teams to emphasize the importance of teamwork and communication in engineering fields. Throughout the semester, the teams are required to utilize the concepts learned in lecture and apply them to the completion of a fun, yet inexpensive design project. In presenting their work, the teams must demonstrate an understanding of the fundamental engineering principles behind their design in addition to simply exhibiting the functionality of their project.

During the Fall 2006 semester, the project facilitates learning of energy systems involving renewable energy sources. Students were required to construct a system that uses solar, wind, and/or hydro sources to collect energy. Furthermore, their system must be able to store, transport, convert, and utilize the collected energy to power a small light bulb. The overall effectiveness was judged based on the amount of energy that can be collected and distributed via the system versus a cost analysis for its design.

Overall, the course is setup to combine the apprehension of fundamental engineering concepts in lecture with their application during the design project. This particular project is important because it educates aspiring engineers about renewable energy sources. The development of such systems that are efficient and effective are becoming increasingly vital to economical, industrial, and social growth worldwide. As part of the *INSPIRES* (*IN*creasing *S*tudent *P*articipation, *I*nterest and *R*ecruitment in *E*ngineering and *S*cience) curriculum (funded by the National Science Foundation – Instructional Materials Development ESIE program), a web based tutorial and computer simulation has been developed for this energy system design project. The web based tutorial features interactive animations and design simulations that allows students to adjust parameters to investigate the effect that each has on the efficiency of their simulated design. In addition, the on-line tutorial features pre and post assessments on content knowledge of the design process and underlying concepts. The results of these assessments will be compiled and presented.

Background

The University of Maryland, Baltimore County has recently seen alterations made to the Introduction to Engineering Course (ENES 101) from a traditional lecture and design-on-paper course to a more active learning and hands-on experience. This transition has been ongoing for the past six years through the institution of several changes and additions to the course curriculum. While the course still offers two fifty-minute sessions of traditional lecture about introductory engineering principles each week, an additional two-hour hands-on discussion session as well as a team oriented final project has been added in an attempt to improve the overall effectiveness of the course. It is the philosophy of the course developer, who is a co-author of this paper, that students respond to concepts better when presented with the opportunity to truly become involved in their learning rather than simply being required to attend a semester-long series of lectures and complete written work based on them.

The addition of the design project and smaller discussion based learning also allows the course to fulfill additional goals on the UMBC Chemical and Biochemical Department ABET objectives and outcomes, known as the "5C's." According to the "5C's," students should demonstrate, upon graduation, **C**ompetency in the discipline of chemical engineering, **C**ritical thinking ability to solve complex problems, the ability to work in **C**ooperation with teammates, effective **C**ommunication skills, and **C**apacity for life-long learning.[1] Instead of only accomplishing goals within the competency in the engineering discipline and critical thinking objectives, the addition of a hands-on, group-oriented design project requires students to complete work regarding the aspects of teamwork and communication of ideas and further enhances items which were already being accomplished.

Just in the past three years, the course has been geared towards assisting the introduction of incoming freshman to the university experience by utilizing a student who recently completed his/her undergraduate coursework at UMBC as the teaching fellow (TF) assigned to lead all of the discussion sessions. This provision was added in an attempt to make students become more comfortable with their new surroundings by offering them an insight into their immediate future from a mentor who would be extremely familiar with the scenario. Also over the past two years, the course project has operated several times in conjunction with the *INSPIRES* (*IN*creasing *S*tudent *P*articipation, *I*nterest, and *R*ecruitment in *E*ngineering and *S*cience) curriculum, an NSF funded IMD grant (ESIE-0352504) that is also being developed in the Chemical and Biochemical Engineering Department at UMBC.[2] In the fall of 2006, it was determined that useful data could be obtained as to the effectiveness of solely the design project for an *INSPIRES* module by asking students to complete an assessment prior to and following the completion of the design project. This data would not only judge the level of learning that students obtain by performing a hands-on design project in the introductory course, which is presented in this work, but also provide a basis for comparison of completing the entire *INSPIRES* module versus only the final design project.

Design Project History[3]

Over the past six years, there has been a variety of design projects assigned for completion in ENES 101. In the fall of 2000, students were challenged to design, construct, evaluate, and test a human powered pump. Following an allotted fifteen-minute assembly period and ten minutes of pumping time, the device was required to draw water from a large tank, pump it up a minimum vertical height of ten feet, and deposit the water in an adjacent empty tank. Another project, which has been used several times in the past six years, is the design of a catapult or trebuchet. Students were given a series of design specifications, with their final product being tested for launch distance and accuracy using water balloons for ammunition. In the fall of 2002, the ENES 101 class project was the design of a hot air balloon. Requirements for this activity included staying aloft for a minimum time of twelve seconds while carrying a minimum payload of ten grams and maintaining the design within size and cost restrictions. The following semester, the design project was to create a device that would transport a wooden block utilizing only the energy of a sealed two-liter bottle of soda. Students were again tested for distance and accuracy while being held to size restrictions and being prohibited to allow any liquid or gas discharge. In the Fall 2004 semester, the activity that was utilized was the design of a chemically-powered vehicle. Teams were required to use this vehicle to transport a given payload across a specified horizontal distance in order to force them to demonstrate control of a chemical reaction. Size restrictions and the prohibition of releasing any material other than a harmless gas were set as guidelines for students to follow.

Also in Fall of 2004 was the first time that the ENES 101 project would be used in conjunction with the development of the *INSPIRES* curriculum by assigning one section of the class to complete the final project of the Engineering in Health Care module: creating a simulated hemodialysis system. Students were required to design, construct, generate prediction models, test, and evaluate their device with the objective of removing a minimum amount of impurities from simulated blood while minimizing the use of a dialysate (water). In achieving their goal, students were also challenged to minimize the cost of their system and attain an accurate model, both of which played a role in judging project effectiveness.

The 2006 Design Project: A Renewable Energy System

The Fall 2006 design project for the ENES 101 course at UMBC was to design, construct, test, and evaluate a device that simulates a system for collecting, storing, transporting, converting, and utilizing renewable energy. The overall goal of the project was simply to be able to light a 1 cell AAA Maglite® light bulb after being allowed to collect energy for up to two hours.

Students were given the option to utilize water at an approximate flow rate of 0.5 liters per second, solar energy provided by a 90-watt flood light, or wind energy provided by a box fan with settings of 166 watts, 117 watts, or 87 watts. In addition to providing the above means of energy, the course instructor also provided a variety of solar cells, DC motors, gears, and rechargeable batteries with holders that teams could borrow for use in their system. All supplies were purchased by the Chemical and Biochemical Engineering Department at UMBC under the NSF funded **S**cience, Technology, Engineering and Mathematics **T**alent **E**xpansion **P**rogram (STEP-DUE-0230148).

The primary criterion for the design project was **SAFETY**; the system must operate without any hazards. There was a cost restriction of $100.00 placed on the overall design, which must include **ALL** parts utilized in the design. While students were encouraged to scavenge and use materials from sources outside the program, they were required to price those as if they were newly purchased. Lastly, students were required to maintain a design notebook (provided by the instructor) which provides documentation of the design evolution, including a log of each team meeting, preliminary sketches and calculations, and reasoning for the final design.

System performance was judged based on the power generated, system efficiency and device cost index as used in the formula below:

Power Generated **x** ***Overall System Efficiency*** **x** ***Device Cost Index***

Power generated refers solely to the ability of the system to light the light bulb. It is determined by the maximum current and voltage that the device produces as measured using a multi-meter. The overall system efficiency is calculated by dividing the useful work output by the energy input. The useful work output reflects the amount of work that the system outputs in lighting the light bulb while the energy input reflects the amount of energy put into the system during the collection time. The device cost index simply refers to the minimum design cost of all functioning energy systems from the ENES 101 class divided by the cost of that team.

Following the testing of the final product, all teams were required to organize their ideas into a formal written report and brief oral presentation. Each group was expected to provide background for the process they selected and reasoning behind all of the decisions made during the evolution of the final design. In addition, the reports were required to include a look at the safety aspects of the design, calculations for all of the values necessary to determine system performance, justifications for the calculations utilized and decisions made during the semester, conclusions regarding the results obtained during product testing, and suggestions for possible changes they would make to the design and/or for future experimenters in the field. Students were graded based on a distinct rubric for both the presentation and written report, as well as peer evaluations from their classmates and teammates. Overall, this comprised 30% of the overall grade for the course. There was also a question on the final exam requiring calculations based on determination of the system performance for the design project.

Beyond preparing reports, students were also assessed based on a short, multiple-choice assessment that was given both on the day the project was distributed and the final testing day. An analysis of this data was expected to reveal the effectiveness of the hands-on project in educating students about energy issues.

Results and Discussion

At the outset of the semester, the primary goal was to determine if the renewable energy project would be feasible to utilize for an engineering curriculum. Essentially, it was desired to remain an inexpensive, but fun activity that offered a variety of choices and experimentation for students to use the concepts they learned about energy to develop an efficient, functioning system. The project was ultimately deemed a success because it was determined that all three possible choices for renewable energy sources could result in a successful final product. In fact, one of the design teams was able to light the bulb for over eight hours! Figure 1 exhibits one example of each type of renewable energy utilized for the design project.

Figure 1: Project Examples

For the first time since the ENES 101 course was restructured, there existed the opportunity to analyze the effect of a hands-on design project on the learning of a participating student. This analysis was done by asking students to complete a seventeen-question multiple choice assessment prior to and following completion of the design project portion of the course. The questions asked were taken from the pre/post test for the Energy Solutions module of the *INSPIRES* curriculum. Before the project began, 122 students submitted a pre-test of which the average score was 10.78 correct responses out of a possible seventeen. At the conclusion of the project, there were 100 post-tests collected which generated an average score of 11.56, for an improvement of 0.78 points per student.

In addition, a comparison was done between the pre- and post-tests of the 100 individuals who completed the assessment each time. This analysis revealed that 54% of students increased their score on the same seventeen questions after completing the design project. Figure 2 below shows the percentage of students attaining each score on the respective assessment. It is easily noticeable that the scoring curve shifts to the right on the graph indicating a successful increase in student knowledge about energy systems. Furthermore, the largest increase in percentage of students achieving any one score occurs at the highest score achieved, 15. Since the average increase in score was less than one point, this suggests that students with a higher aptitude in the field already were more likely to increase their knowledge as a result of this project.

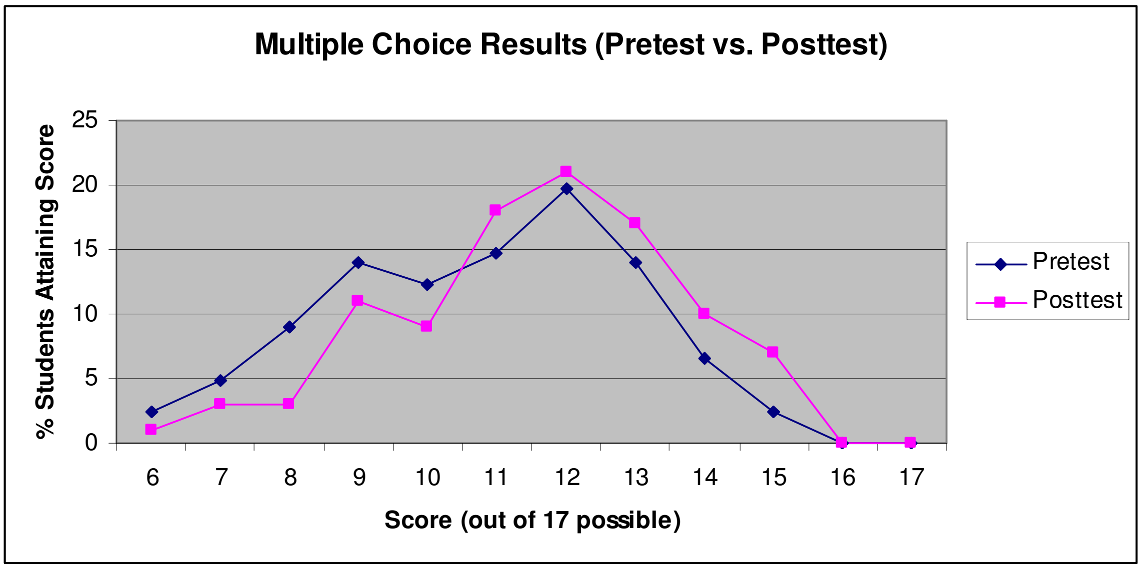

Figure 2: Graphical Analysis of Pre-test Results versus Post-test Results

Upon completion of the data analysis, it was shown that students demonstrated an increase in knowledge about renewable energy sources. This fact is clear simply by analyzing the above results for an identical assessment given before and after completion of the design project. It should be noted, however, that the percentage of students who increased their score, as well as the average score increase, were not as high as expected by the course evaluators.

There were several factors which may have limited the general improvement for students on the assessment. First, students were told that the pre- and post-tests were only research tools that were not going to be factored into their overall course grade. This makes it quite likely that a number of students failed to take the assessment seriously, even though the importance of their full participation to this research was expressed. As noted under future work, the ENES 101 students of the spring 2007 semester will have their final grades affected by assessment performance, which will allow determination if this fact truly affected the results.

A more important issue is that not all of the questions asked on the assessment regarded topics that were directly addressed in completing only the design project. Since the project was occurring in conjunction with the *INSPIRES* curriculum, it made sense to also utilize the pre- and post-test questions for the module in which this project is featured. However, students participating in the entire module will also experience a number of web-based tutorial sessions that will cover concepts regarding energy which are not specifically reflected in completing the project alone. Better results would have likely been obtained if a new assessment was developed pertaining only to items which would be learned by completing solely the design project. Even though several of the questions given would fall into this category, the scoring was ultimately skewed by students being asked to essentially guess at questions of which they had no prior knowledge and which were not covered during the course. This issue will also be addressed as the study continues into the Spring 2007 semester.

In addition to the assessment, general observations and conversations on the day of testing offered evidence suggesting students were learning cooperatively from the hands-on experience. Furthermore, several students expressed the enjoyment and insight that they were able to gain as a result of being given a difficult, teamwork challenge. Each of these facts was demonstrated again when observing the required oral presentations. Unfortunately, there were no questionnaires distributed to the class in an attempt to quantify the effect of the project and the course in general on the freshman experience at UMBC, interests in the field of engineering, and student perception as to how much they have gained from their work. This idea is likely to be added upon utilizing the project for additional future semesters of ENES 101.

In addition to the pre- and post-tests, students are also asked to complete **S**tudent **A**ssessments of **C**ourse **O**utcomes (SACO). On these surveys, students respond to questions regarding the effectiveness of the course in achieving the ABET objectives, as set forth by the Chemical and Biochemical Engineering Department (The "5C's"). From these data, students reflected that the ENES 101 course contributes greatly to their ability to work in teams, fulfill both leadership and supporting roles within a team, and the ability to locate the necessary tools and information when given an open-ended problem. All three of these categories received an average rating of 4.4 out of 5, where 5 is representative of the class contributing a great deal to the category and 1 corresponds to no contribution. The students were also asked to proved open-ended responses on the SACO to "What was the best part of the course?". Over 60% of the responses indicated that the design project was the best part of the ENES 101 course.

While the desired level of increase of student aptitude may not have been fully achieved by this project, the consensus opinion of participants was that success was attained. Furthermore, utilizing this activity for Fall 2006 students has brought the necessity for alterations in administering the project in the future to the attention of the course instructors. This will likely lead to improvement of the course in the near future, offering further enhancement of the freshman experience as well as student knowledge and preparation within the engineering department. The past six years, again exhibited in the

Fall of 2006, have certainly shown that the use of hands-on activities to supplement traditional lecture increases student knowledge, interest, and enjoyment for the field of engineering.

Future Work

In the upcoming Spring 2007 semester, ENES 101 students at UMBC will be assigned the same overall design project, complete the same pre- and post-test assessments, and experience the same instructor and teaching fellow. The difference in the study will be the addition of the entire Energy Solutions module from the *INSPIRES* curriculum. Instead of omitting the module completely, two of the four sections will be assigned to complete the entire web-based tutorial including the design project while the remaining two sections will complete only the final project. In addition, it is anticipated that student performance on the assessment will factor into their overall grade in the class to ensure that complete effort is given. Furthermore, it will be possible to analyze the student responses to the final exam question about the design project in an additional attempt to judge the impact of the project and/or module on learning. This will provide three sets of data for comparison: Fall 2006 (no module, no grading), Spring 2007A (no module, inclusion in grading), and Spring 2007B (module, inclusion in grading). It is hoped that this data will provide a distinct look at how the addition of a design project affects the overall learning in ENES 101 while also offering a look into the effectiveness of the *INSPIRES* curriculum module and student motivation on the Fall 2006 assessments. It is hoped that a portion of this work will be completed for inclusion in the presentation at the conference in June.

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