Session 2793

Forging New Links: Integrating the Freshman Engineering Curriculum

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Abstract

The School of Engineering at Western New England College is redesigning its traditional core curriculum to provide Freshman engineering students with a more integrated and challenging educational experience. We began this evolutionary process by creating two new courses for the Fall 2000 semester – a new four credit hour course called *Introduction to Engineering* and a one credit hour *Engineering Seminar*. The content of the new *Introduction to Engineering* course focused on learning the engineering design process and some of the tools (such as graphics, CAD, and various computer packages) needed to support that design process. This course was designed with a significant portion of its content devoted to hands on exposure to engineering design. The students experienced the entire design process twice during the Fall semester using RoboLab™ by LEGO-DACTA as a platform to solve engineering problems. In the one credit hour *Engineering Seminar*, students learned strategies needed to be a successful engineering student (such as time management, test taking strategies, and oral and written communication skills) and were acquainted with various aspects of the engineering profession through trips to local industry and seminars given by practicing engineers.

The *Introduction to Engineering* course was broken into four identical sections, each with fewer than 25 students enrolled. The faculty member teaching the section also served as the academic advisor for the students, allowing the faculty members to better advise students on their academic and professional pursuits. Faculty coordination and cooperation were cornerstones to the successful delivery of course materials. The new courses and curriculum structure were a success because the freshmen were able to demonstrate an understanding and ability to use the design process to solve engineering design problems.

I. Introduction

In many cases a liberally educated engineer going into the workplace for the first time does not appreciate how the various components of his/her education are linked until those links get forged during the practice of engineering. A traditional engineering curriculum is constructed along the lines of... an engineer needs to know about X so make a course that teaches X, it is important for an engineer to know something about Y so here is a course that teaches Y. Are X and Y related? They might be if they are part of a discipline or course sequence but the relationship may be more academic than practical. Academic programs tend to be built of 'knowledge blocks'. A course tends to be a compartment within a curriculum of compartments. Each course focuses on some topic or closely related group of topics that are not treated in any other course. The working assumption seems to be that once a student is exposed to some particular piece of information in a particular course that student has mastered it and will able to recall and use it at any time for the rest of his or her life. For example, assuming the material presented in Freshman English Composition courses will be used proficiently for a major engineering report in the senior year three years later. Unless the knowledge gained in the composition class is incorporated explicitly into the engineering classes throughout their education, the students will have difficulty retaining and using the knowledge at discrete milestones (e.g. the capstone design final report).

In order to reduce compartmentalization of information and promote the routine exercising of important skills over time, the School of Engineering at Western New England College is redesigning its traditional common core curriculum to provide Freshman engineering students with a more integrated and challenging educational experience. Our ultimate goal is that the concepts being developed to redesign the Freshman curriculum will be used to redesign the entire curricula of the engineering programs (ME, EE, IE, and BME). The term, integrated, in this case refers to the integration of engineering courses only and not math, physics, and English courses referred to by other authors such as [1, 2]. In the next phase of our curriculum redesign these other academic areas will be considered as well (through an interschool curriculum committee).

II. New Curriculum Structure

The redesign process of the Freshman curriculum is evolutionary. Two new core courses have been introduced into the Fall 2000 semester of the engineering curriculum – a new four credit-hour course called *Introduction to Engineering* and a one credit-hour course called *Engineering Seminar*. The content of the new *Introduction to Engineering* course focuses on learning the engineering design process and some of the tools (such as graphics, CAD, and various computer packages) needed to support that design process. This course was designed with a significant portion of its content devoted to a hands-on exposure to engineering design. The students experience the entire design process twice during the Fall semester using RoboLab™ by LEGO-DACTA as a platform to solve engineering problems. In the one credit hour *Engineering Seminar*, students learn strategies needed to be a successful engineering student (such as time management, test taking strategies, and oral and written communication skills) and are acquainted with various aspects of the engineering profession through trips to local industry and seminars given by practicing engineers.

The scheduling and structure of *Introduction to Engineering* provided an environment that encouraged active participation by the students and promoted a strong interaction between the engineering faculty and Freshman students. The focus of engineering design dictated the choice of course material, provided the linking mechanism between the various components or modules of the course and controlled the number of students in a section. For the design portions of the course, it was decided that the Freshman would work in teams with no more than four members. Class size was limited to 24 students by having each instructor responsible for no more than six teams. Instructors were assisted by student aids who also functioned as peer advisors for the entire freshman experience. To accommodate the entering Freshman class, four sections of the course were created.

Delivery of course material was based on a weekly schedule of fifty-minute 'activity hours'. There were six such hours in a week: Design Hour 1, Design Hour 2, Graphics Hour, Computer

Support Hour, Computer Hour, and CAD Hour. In order to efficiently use available resources (e.g. computer and CAD workstations), the activities of each class were not synchronized on a daily basis, but rather on a weekly basis. Even though each section met twice a week during the same three-hour period, the activity during each hour was not the same for each section.

The schedule of activity hours per week was flexible. If more time was needed for graphics activity and less for design activity then there could be one design hour and two graphics hours for that week. There was no requirement that the length of an activity be exactly fifty minutes. Activities did not have to take place in the same classroom during scheduled class times (some activities required laboratory facilities while others required computer facilities). Seating in a classroom changed as a function of activity (individual effort versus team effort).

The *Engineering Seminar* course provided additional opportunities for the Freshman to learn about engineering and to be a successful engineering student. The course also served as an additional resource for Introduction to Engineering. The class met once a week for up to three hours. Students met in a lecture hall to receive general information, listen to guest speakers, or participate in special workshops. For activities that required more individualized attention students, in groups of twenty five or less, went to 'breakout' rooms. A typical class might consist of a general meeting lasting about twenty minutes in the lecture hall and then a fifty-minute activity in the breakout rooms. Tours of engineering facilities at local companies took up the full three hours of class time. Topics and activities covered in *Engineering Seminar* were:

- Time management
- Team building (study groups, engineering teams)
- Studying strategies
- Test-taking strategies
- Using the library
- Writing an engineering report
- Giving an engineering presentation
- Panel discussions involving professional engineers as panelists
- Engineering Majors open house
- Professional Societies open house
- Touring local industry
- Laboratory time for optimizing designs
- College-wide requirements (focus programs involving all Freshman on campus)
    - Money management
    - Campus services
    - Diversity awareness
    - Substance abuse
    - Responsible dating

Engineering Seminar had a college success skills component to satisfy college-wide requirements as well as an engineering success skills component. Whenever possible, the topics mandated by college-wide requirements were put into an engineering context to provide greater relevancy for the engineering student. Topics in the seminar course were selected and arranged to compliment the activities in Introduction to Engineering. For example, students got two perspectives on how to give an oral presentation. They got an overview and a workshop in *Engineering Seminar* and a more detailed lecture with hands-on exercises in Introduction to Engineering. Some topics were introduced to help the Freshman decide if engineering was for them or to help decide what branch of engineering was right for them. To promote learning, students had to submit reports on what they experienced at special activities such as panel discussions, open houses, or industrial tours.

III. Faculty

The four instructors for the *Introduction to Engineering* course represented each of the engineering disciplines (BME, EE, IE, and ME). Students that had declared a discipline were assigned to the appropriate instructor. Students that were undecided as to which branch of engineering they wanted to study were distributed among the sections to balance the student count between sections. This assignment strategy allowed the students to 'connect' with the engineering faculty and the profession quickly. Moreover, the instructor of each section also served as the academic advisor to their students allowing further faculty-student interaction and tracking of student goals and progress.

The major pieces of course content and topic scheduling was designed by the faculty over a two-month period during the summer prior to offering the course. Topic details and minor scheduling changes were worked out on a weekly basis as the course progressed. The instructors of the course met at the end of each three-hour class period to critique the class work and to outline the details of the class content and logistics for the following class and the following week. As has been pointed out in many references (such as [3]), the workload for this kind of course is at least double what it is for a 'regular' Freshmen course. An instructor for this course has to be an 'expert' in graphics, CAD, computer hardware and software, engineering design, and project and team management.

IV. Student Teams

Members of a Freshman design team were selected by using the results of Belbin's personality type questionnaire (administered before classes started during summer registration and orientation) [4]. Each team had a balanced mix of personality types (idea sources, detailers, finishers, etc.).

V. Course Content

The following outlines the content of the various activity areas used in the course.

1. <u>Design Activity</u>:
   - 1.1. Summer orientation class in engineering responsibilities and ethics
   - 1.2. Presentation of the engineering design method, tasking a project, design-team behaviors and responsibilities (including team contracts), engineering reports (oral and written)
   - 1.3. Design competition problem 1 - Design a scale model of a material mover that can move the most material in the shortest possible time.
     - 1.3.1.1. Competition Metric = (mover speed)*(load hauled)/(mover weight)
     - 1.3.1.2. Teams submit progress reports for each design stage
     - 1.3.1.3. Faculty act as company management and design team supervisors
   - 1.4. Design competition problem 2 - Prototype a self-powered, autonomous robotic system that will travel a meander course as quickly and as accurately as possible under unguided conditions; at the end of the course it is to seek out and drive to a light source located anywhere on an arc with a radius of two feed from the course's exit. Upon reaching the light source the robot is to power itself down.
     - 1.4.1.1. Competition Metric for this design involved speed and accuracy

1.4.1.2. Teams submit progress reports for each design stage
1.4.1.3. Faculty act as company management and design team supervisors

2. Graphics Activity (principles and exercises presented in a 'workshop' environment):
   2.1. Using proper lettering and sketching techniques
   2.2. Visualizing in 3-space
   2.3. Generating views from solid objects and vice-versa
      2.3.1. Conventions in creating and interpreting drawings
   2.4. Creating complex graphical objects from simple primitives
   2.5. Conventions for dimensioning objects and creating assembly drawings
      2.5.1. Students create assembly drawing of a section of robot used in second design competition
   2.6. Reading blueprints and assembly drawings

3. Computer-aided Design:
   3.1. Introduction to the IDEAS graphics package
   3.2. 2D sketching; construction tools and their use
   3.3. Techniques for creating 3D objects (both wireframe and solid)
   3.4. Making a 'shop drawing'

4. Computer Tools:
   4.1. Research on the Web
   4.2. Plotting data in Excel and determining empirical equations from data
   4.3. Methods for creating a proper PowerPoint presentation
   4.4. Working in the RoboLab™ environment
   4.5. Numerical calculus (using Excel)

VI. Design Projects

The backbone of our course was the engineering design process similar in philosophy to methods cited in [5,6,7], rather than the reverse engineering method recommended by Burton and White [3]. All of the topics and activities centered on support of the design activities. For example, sketching and CAD skills were developed early enough so that they could be used to document design concepts and present information appropriately in the interim and final design reports. As should be expected, students were more proficient in their graphical skills for the second design project compared to the first. In a similar manner, word processing, PowerPoint, and Excel skills were developed early enough to aid in creating, documenting, and presenting designs. Assignments for the various activities had to be carefully coordinated so that students were not over burdened one week and had nothing to do the next. Typically a student would have graphics or computer homework due every class and a quiz a week. Additional work involved short reports on the progress of a design.

To insure that the students would get a firm grasp of the engineering design process the first design project was broken into stages. Each stage illustrated a particular aspect of the design process. Each stage had a lecture component followed immediately with a laboratory experience to clarify the principles presented during the lecture. For example, in order to teach brainstorming, a short lecture would be given on the brainstorming process then the teams were told to assemble and brainstorm solutions to their design project. The class instructor and teaching assistant would circulate among the teams providing assistance and direction as needed.

To reinforce the information gained during each stage the students were required to write a short report on their activities for that stage. Each short report became the material for writing the final engineering report for the project. Each short report was critiqued, graded, and returned to the student for further action. That is, the student had the option of making changes to the graded report and resubmitting it for a better grade. This approach provided additional learning opportunities as well as motivation for improving the students' work. It was the responsibility of the class instructor to grade and return these reports at the next class meeting in order for the feedback to be timely and meaningful.

The first design project was made elementary so that the student could easily understand what had to be done and could therefore concentrate more effort on learning the design process. The project involved designing a material transport system (using LEGO™ components) The goal was to move pallets loaded with as much material as possible as quickly as possible along a ten-foot straight track. To stimulate motivation in the design project a competition was created within each section. The team that succeeded in getting the largest value of the metric defined as (transport speed)*(load hauled)/(transport weight) would win the competition and win a prize determined by each instructor (e.g. drop the lowest quiz and/or homework grade) from the course grade. The students were provided with a pallet and two pound weights that simulated the manufacturing material. One of the responsibilities of the design team was to calculate (by methods learned in their Freshman physics class as well as by handouts given in this class) the maximum capacity and speed of their system. The teams were given information on how to determine the amount of power available from the LEGO™ power packs, how much power was consumed by their DC motors as they developed varying amounts of torque, how various gear arrangements controlled torque and speed, and how to measure the coefficient of sliding friction and use it to calculate the maximum load that the system could move. Thus, a team had to theoretically predict design performance and then verify that prediction through experimentation.

The second design project was more challenging than the first since it involved both hardware and software design. The project was 'staged' like the first but with fewer stages and more content per stage. The design teams were expected to do more work on their own. The project involved designing and programming a robotic vehicle that could travel a given meandering path then seek out and travel to a light source placed anywhere along a finish line as shown in figure 1 below.

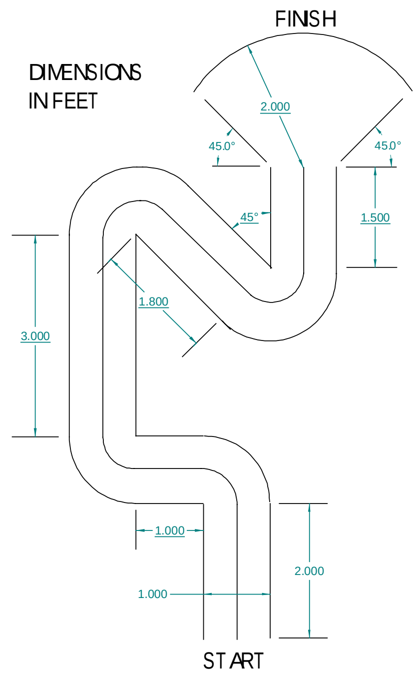

Figure 1 – Course for the vehicle of design project 2

This project involved a competition between all engineering teams. The robot that traveled the path quickest without going outside the boundaries won the competition. The first and second prizes were gift certificates to the College bookstore. Travel along the path was by open-loop program control. That is, the robot could not use sensors to determine if it was on the path or not. The design solution was to determine how much time it took the robot to travel a measured straight line and a portion of a circle and then use those experimental results to set timing structures in the robot's program. The design teams quickly learned that such things as the mechanical structure of the robot, level of power in the robot's power pack, and condition of the track surface greatly affected the robot's ability to navigate the track. The light source at the finish line of the track was a three-cell Maglight™ flashlight mounted on a three-inch tall wooden block. Design solutions involved some sort of search program to determine the location of the light source then some sort of hunter-seeker program to stay centered on the light source while the robot moved. Some designs used one light sensor while others used two. Teams were much more successful in locating and getting to the light source than in navigating the meander track. There was no grade penalty for a disqualification during competition. However, there was a grade penalty for not doing a proper engineering job.

VII. Assessment

The course structure is viable. It allows efficient use of limited computer and classroom resources while providing a challenging working and learning environment for faculty and students. The workload for the faculty involved was heavy. A summer grant has been secured to find ways of reducing the workload while maintaining the same teaching objectives and learning experiences. Screening incoming Freshmen during summer orientation using Bilbin's personality type questionnaire is helpful in setting up design teams and will be continued. A number of refinements and changes in the course content have been noted during the teaching of this course. Some changes will be made to the graphics portion, there will be additional material related to professional ethics, engineering economics, and the use of computers as a design tool as well as a communications tool. The design projects will be changed in order to overcome some shortcomings. The first project needs a problem statement that allows more than one solution but encourages the engineering process instead of allowing 'tinkering' to get a final solution. The second project needs a set of objectives that allow more design successes. The present form of the project allowed only one out of twenty-four design teams to run the test track successfully.

VIII. Conclusions

Introduction to Engineering and *Engineering Seminar* provided an integrated approach to teaching the engineering design process to Freshman. Working with a more diverse mix of topics and a more open-ended class and laboratory schedule kept students more alert and engaged in their course work. Using design projects with objectives and outcomes obtainable by Freshman kept them focused and on task for extended periods of time (inside and outside of the classroom). Dividing a large design project into tasks showed the student how to be systematic in thinking about a project and how to make a difficult, time consuming job into smaller, more manageable tasks. Having 'tight' time tables of deliverables for a project forced the students to learn how to budget their time to get each task done on time. Having the Freshman work in design teams provided a mechanism for forcing strangers to come together and learn how to work with each other. The team structure helped students form peer bonds that facilitated their adjustment to college life; many of the design teams became study teams for other courses. One of the objectives of this course was to provide students with information about the field of engineering through hands-on experiences so they could make an informed decision to pursue a career in engineering. Exit interviews with engineering Freshman that changed majors or dropped out of school (slightly over 10% of the entering engineering class) showed that these students enjoyed the course (even though they thought it was hard work) but determined that engineering (or in a few cases college itself) was not for them. Course evaluation questionnaires showed that those students who were uncertain about being an engineer at the beginning of the semester decided to remain in engineering based on their experiences in these courses.

Bibliography

1. Nizar Al-Holou, Nihat M. Bilgutay, Carlos Corleto, John T. Demel, Richard Felder, Karen Frair, Jeffrey E. Froyd, Marc Hoit, Jim Morgan, David L. Wells, First-Year Integrated Curricula: Design Alternatives and Examples**,** Journal of Engineering Education, October 1999

2. Louis J. Everett, P.K. Imbrie, Jim Morgan, Integrated Curricula: Purpose and Design, Journal of Engineering Education, April 2000

3. Julie D. Burton, Daniel M. White, Selecting a Model for Freshman Engineering Design, Journal of Engineering Education, July 1999

4. Belbin, R. Meredith, <u>Team Roles at Work</u>, Butterworth-Heinemann, Linacre House, A division of Reed Educational & Professional Publishing Ltd.

5. J. W. Dally, G. M. Zhang, A Freshman Engineering Design Course, © 1993 American Society for Engineering Education. Reprinted from Journal of Engineering Education, Vol. 82, No. 2, April 1993. Journal of Engineering Education

6. Richard L. Porter, Hugh Fuller, A New “Contact-Based” First Year Engineering Course, Journal of Engineering Education, October 1998

7. Clive L. Dym, Teaching Design to Freshmen: Style and Content, Journal of Engineering Education, October 1994

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