Introducing First Year Students to Externally Collaborative Interdisciplinary Design

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Abstract - In an effort to make engineering education more relevant to the challenges of today's world, the course Introduction to Engineering Design at Wentworth Institute of Technology has adopted an interdisciplinary project-based curriculum. As a result, this course has evolved significantly since this curriculum change was enacted in the year 2011. Since its inception, the course has grown from involving first-year students in one degree program and faculty from two engineering disciplines to five degree programs and faculty from five engineering disciplines. This expansion has presented numerous challenges from both educational and logistical standpoints. These challenges range from issues in forming interdisciplinary student design teams to problems that arise from an effort to pursue external collaborations. The focus of this talk is to present the evolving format for this course along with lessons learned through this process that could help other institutions develop similar initiatives. Recommendations will be made for future developments of first year interdisciplinary project-based courses based on learning assessment metrics, faculty and student surveys, and general observations.

(External collaboration, Interdisciplinary, Project-Based, First Year Design).

BACKGROUND

The emergence of societal challenges that require the use of new technologies and the integration of complex systems has presented a need for interdisciplinary engineering teams in the modern job market [1]. In order to meet these challenges, engineering education must prepare students for an evolving job market through reevaluating how engineers are trained [2]. This can be done though challenging the students with an interdisciplinary design environment and by presenting them with real world problems that require complex and creative solutions. At Wentworth Institute of Technology, the course Introduction to Engineering Design has been developed to present first year engineering students with an interdisciplinary design environment so as to make this philosophy a cornerstone of their education.

The College of Engineering and Technology at Wentworth Institute of Technology in Boston, MA is comprised of 7 Engineering majors for whom approximately 420 first year engineering students enroll annually. Of these majors, 3 are inherently interdisciplinary; biomedical engineering, electromechanical engineering, and interdisciplinary engineering. Starting in 2011, the course Introduction to Engineering Design adopted an interdisciplinary approach for both the makeup of the course instructors and enrolled students.

This paper outlines the continued evolution of this course and makes recommendations based on lessons learned. Throughout the 4 year evolution of this course, students have been routinely polled to indirectly assess their understanding of the design process as well as gain their general observations on the course. Direct assessment has also been performed on numerous learning assessment metrics such as the students' ability to function in multidisciplinary teams, the ability to engage in lifelong learning, and the ability to design a system, component, or process with realistic constraints. Student performance has both risen and dropped in various criteria over the duration of this study; all of which has contributed to the continued evolution of this course.

In this ongoing study, the coming year will present the first opportunity to assess graduating students that have taken this course as first year student in 2011. This data will provide a quantification of the effectiveness of this approach to engineering education and also guide future iterations of this course.

COURSE EVOLUTION

Starting in 2011, a pilot program was adopted through the course Introduction to Engineering Design wherein a focus was placed on interdisciplinary project based design. For this pilot program, the major 'Electromechanical Engineering' was used due to its inherently interdisciplinary makeup of the student body. The faculty instructing the course was comprised of one Electromechanical Engineering instructor and one Biomedical Engineering instructor. In this first iteration of the interdisciplinary format, all students worked in 3-4 student design teams on one predefined project that had significant electrical, mechanical and biological components. Throughout the semester both course instructors applied their expertise in advising the design teams. In this exercise, students were able to seek advice from experts in the various disciplines associated with their project.

The successful implementation of this pilot program lead to an expansion in 2012 to include Biomedical Engineering students. With this course expansion, a similar format was adopted by the course instructors wherein students were advised by experts in two disciplines. Although the course was effective in introducing students

Year	2011	2012	2013	2014	2015
Student Enrollment	Electromechanical (~40 students)	Electromechanical Interdisciplinary (~60 students)	Biomedical Electromechanical Interdisciplinary (~120 students)	Biomedical Civil Electromechanical Interdisciplinary (~220 students)	Biomedical Civil Electromechanical Interdisciplinary Mechanical (~420 students)
Instructors	Biomedical Electromechanical (2 Instructors)	Biomedical Electromechanical (2 Instructors)	Biomedical Computer Science Electromechanical Interdisciplinary Mechanical (6 Instructors)	Biomedical Civil Computer Science Electromechanical Interdisciplinary Mechanical (9 Instructors)	Biomedical Civil Electromechanical Interdisciplinary Mechanical (12 Instructors)

TABLE I
THE EVOLUTION OF INTRODUCTION TO ENGINEERING DESIGN

to an interdisciplinary design environment, it was limited to the disciplines of the course instructors. In order to address this limitation and to allow for the course to be offered to more engineering majors, the Introduction to Engineering Design Committee was formed in 2013. The committee was comprised of faculty members from 5 disciplines as well as the Dean of the College of Engineering and Technology. Under the purview of the committee, the course has grown in every subsequent year in both numbers of students as well as well as engineering student majors. Table I illustrates this continued expansion of this course in the subsequent years leading to the current format in 2015.

COURSE FORMAT

Based on the lessons learned from the preceding iterations of Introduction to Engineering Design, the 2015 iteration took on the following format.

- Lecture - 2 hours /week
  - Lectures focus on topics related to the design process.
  - Weekly quizzes are conducted to evaluate student understanding of lecture topics.
- Laboratory - 4 hours /week
  - First 3 weeks students are guided through a predefined design project
  - Weeks 4-15, students work in 3 student interdisciplinary design teams on developing a solution to a loosely defined problem.

Lecture Structure

The lecture component focuses on topics related to the multistep engineering design process. These topics include detailed lecture on the various steps of the design process, design evaluation and failure analysis, intellectual property, and design for sustainability. All lectures are followed by a weekly quiz that evaluated the students' understanding of each topic. Along with the quizzes, students are expected to integrate their understanding of these topics into their semester project. The details of the semester project are discussed in the following section on the structure of the laboratory component of the course.

Laboratory Structure

The interdisciplinary nature of the course is fully realized through the laboratory component and the semester design project. All students, regardless of chosen major, are assigned to one of the course instructors to serve as their primary advisor for the duration of the semester. To start the semester, all students are provided a calibration on the design process through a three week guided design. In this students are randomly assigned teams to work through a predetermined design. Upon completing this design and presenting their proposed solution, the students begin their semester project.

The semester design project begins with assigning students to a 3-4 student interdisciplinary teams. Since most first year engineering students have a common curriculum, generating an interdisciplinary team cannot be based solely on their chosen major. In order to generate an interdisciplinary experience, students are assigned teams based on the skills that they bring to a prospective team. All students are polled on their level of experience with skills such as manufacturing, circuit design, computer programing, and various software packages. Using the polling results, teams are assigned with a focus on providing each team with a diverse set of skills.

Following the assignment of design teams, all teams are tasked with selecting a societal issue/need that they will focus on producing a solution for through their semester project. Upon researching and defining their societal issue, all teams are required to outline their secondary project advisors and also to seek an external collaborator(s). The secondary advisors are chosen from the faculty that are instructing other sections of the course whereas the external collaborators are industry professionals that volunteer their time to assist in the student projects. The selection of secondary advisors allows for students to have access to experts in the various engineering disciplines for which their primary advisor is not versed. The external collaborator(s) are utilized by the students to aid in the evaluation of their completed design and also to ensure that their proposed solutions are both realistic and novel.

For the duration of the semester the laboratory periods are broken into three parts. These are primary advisor consultation, secondary advisor consultation, and group work. The primary advisor consultation focuses on both general project management and insight from the standpoint of their chosen discipline. The secondary advisor consultation is used to provide students with detailed guidance in the various disciplines for which their primary advisor is not versed. The group work component is reserved for laboratory time wherein the design teams can develop their designs and also have access to various manufacturing and test equipment. This format is adhered to throughout the semester until the conclusion wherein all design teams present their final designs as poster presentations at the annual Freshman Design Showcase

STUDENT PERFORMANCE

At the conclusion of the semester all students are directly assessed, by the section instructor, in their proficiency in the following outcomes using predefined assessment rubrics.

- Ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability. (Figure 1)
- The ability to function on multidisciplinary teams (Figure 2)

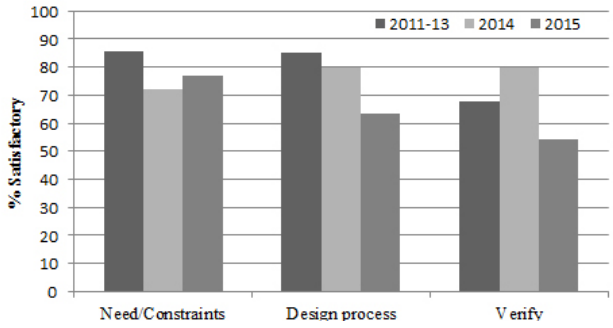

FIGURE 1
Assessment of student ability to design

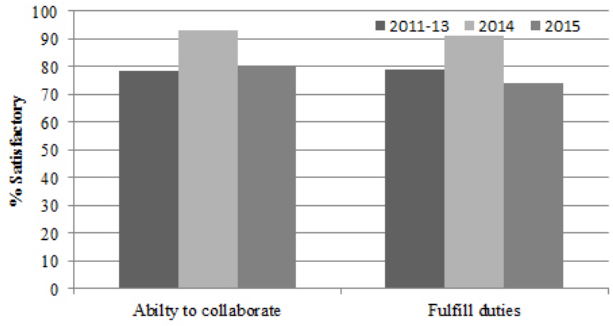

FIGURE 2
Assessment of student ability to work in teams

Through this assessment, it can be seen that various performance criteria have both risen and fallen through the evolution of this course. There are multiple factors that contribute to this. These include the inclusion of more student majors, variations in the course instructors, and the drastic increase in the number of students enrolled in the course. This data should stabilize when the course becomes a requirement for all first year engineering students. Regardless of this, in order to determine the effectiveness of this course on generating a higher quality graduate, assessment must be conducted on graduating seniors that have taken this course. 2015 presents the first opportunity to assess the abilities of graduating seniors and this will serve as a baseline for comparison in future studies.

Student surveys were also conducted at the conclusion of the 2013, 2014, and 2015 iterations of the course. The student experience varied drastically between course sections in 2013. As faculty collaboration improved in 2014 and 2015, the overall student experience became more consistent and positive. It was also found that as the course evolved, that students were more capable of internalizing the design process. This ability to take ownership of the design process is expected to improve performance in capstone design projects [3]. The data collection corresponding to this connection is to be the subject of a future study.

RECOMMENDATIONS

Based on student surveys, assessment data, and general observations, the following are recommendations for institutions seeking similar initiatives.

- Faculty collaboration is paramount to successful implementation. It is imperative that all faculty members collaborate on all aspect of the course and foster a healthy environment for student collaboration

  Rationale: Since all primary and secondary project advisors are selected from the faculty that are assigned to the course, all instructors involved must be capable of working together in concert with the interdisciplinary student teams. The student projects that proved to be the most successful and provide a positive experience for the students often corresponded to strong collaboration between the project advisors.

- Course instructors must be active participants in the external collaboration component. This both fosters relationships for future collaborations and also prevents ruing relationships as a result of unregulated, unfiltered, and potentially excessive, student communications

  Rationale: External collaborators provide insight that would otherwise not be available. However there were numerous instances wherein multiple students design teams contacted the same external collaborator without any oversight from the course instructor. This motivated one external collaborator to withdraw from assisting the teams.

- Through both student surveys and general observations, it was found that developing physical prototypes may not be necessary. Physical prototypes can be a distraction since students tend to focus on component selection and building rather than developing a design.

  Rationale: Two instances of the course, 2013 and 2014, put a strong emphasis on prototyping. Funding was provided to all student design teams and they were strongly encouraged to develop a working prototype. Although students were able to gain valuable insight into designing for manufacturability, many of the other aspects of the design process were overlooked for the sake of building their design. It was also found that developing and constructing a physical prototype put a significant burden on the associated campus facilities.

GOING FORWARD

Based on observations, assessment data, and student feedback, Introduction to Engineering Design will continue to evolve and expand. Starting in spring of 2016, this course will be a requirement for all first year engineering students at Wentworth Institute of Technology. The coming year will also present the next milestone in the development of this study wherein an assessment can be conducted on the proficiency of the first graduating class of student that completed this course.

CONCLUSIONS

The interdisciplinary project based approach to freshman design is an effective means to introduce students to an interdisciplinary design environment. Although assessment of student proficiency in various performance outcomes is inconclusive at this time, the coming years present the opportunity to evaluate the effectiveness of this course format on engineering graduates.

ACKNOWLEDGMENTS

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REFERENCES

[1] Duderstadt, James J. "Engineering for a Changing Road, A Roadmap to the Future of Engineering Practice, Research, and Education." (2007).

[2] Sheppard, Sheri D., et al. 'Educating engineers: Designing for the future of the field'. Vol. 2. Jossey-Bass, (2008).

[3] Donohue, Susan K. "Factors Affecting Student Ability to Internalize the Engineering Design Process." *Proceedings* of the 5th Annual First Year Engineering Experience Conference (FYEE), 2013

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