Work in Progress: Synthesizing an Interdisciplinary Design Environment in First Year Engineering Education

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***Abstract* - The engineering job market is becoming increasingly interdisciplinary in nature. In order to adequately prepare our students for the challenges of this evolving job market, interdisciplinary design environments have become commonplace in engineering education. This, however, presents a challenge in first year classes in that a vast majority of students enrolled in engineering programs have little or no experience in their selected disciplines. To address this constraint, in the spring of 2016 select sections in the course 'Introduction to Engineering Design' at Wentworth Institute of Technology in Boston, Massachusetts have adopted a skills-based synthesized interdisciplinary design environment. This approach assigns student groups based on each student's proficiency in skills that are typically applicable to first year engineering design. For this study, these selected sections are compared to the remaining sections that adopted the more traditional approach of forming groups based on the students' selected engineering disciplines. In this ongoing study, initial results from both, student surveys and direct assessments, indicates the promise of this approach in first-year engineering education.**

Index Terms – Interdisciplinary Design, Teamwork, Design Process, Project Based Learning (PBL)

INTRODUCTION

In order to prepare students for the challenges of a modern job market, engineering education is becoming increasingly interdisciplinary with added emphasis being placed on Project Based Learning (PBL) methodologies. This requires that engineering students be faced with design problems [1] early in their education. Implementing an effective instruction in engineering design through a project based approach presents numerous challenges [2] in that instructors have to balance an authentic experience without sacrificing essential technical content. These challenges are compounded through the attempt to simulate an interdisciplinary design environment.

Combing various engineering disciplines into first year courses is commonplace in many engineering programs and, based on the various disciplines present in one course simultaneously, present an opportunity to immerse students in an interdisciplinary design experience. However, since most students have a common curriculum, combining students into groups based on their chosen discipline provides little insight into a true interdisciplinary design environment. Using the definition of a 'True Team', as described by Katzenback and Smith, wherein a team is comprised of 'people with complementary skills who are committed to a common purpose,' [3] a skills based synthesized interdisciplinary design environment is proposed in this study.

Numerous inquiries have been conducted to analyze group dynamics and instruction methodologies in first year engineering education [4-6]. In contract, in this study, the authors attempt to immerse students into a design environment wherein the application of each individual student's skills is required for the overall success of the team and the project.

COURSE DESCRIPTION

The course 'Introduction to Engineering Design' (ENGR1500) is a freshman level, three credit course offered from the College of Engineering and Technology at Wentworth Institute of Technology in Boston, Massachusetts [7]. As a required course in a common first year curriculum for Biomedical, Civil, Computer, Electrical, Electromechanical, Interdisciplinary and Mechanical Engineering majors, annual enrollment in ENGR1500 exceeds 500 students. To adequately represent the interdisciplinary student makeup of the course, ENGR1500 is designed, instructed, and evaluated by an interdisciplinary cohort of faculty from the Biomedical, Civil, Electrical, Interdisciplinary, and Mechanical departments. All faculty involved in the course comprise the Introduction to Engineering Design committee.

The course is comprised of one hour of lecture and four hours of laboratory per week. Through a series of modifications to the overall course structure since 2011, the 2016 iteration of this course adhered to the following format.

- Lecture - 1 hour /week
- Using a flipped classroom format, prior to attending class, students review lectures that focus on topics related to the design process.

- During the lecture period, course instructors guide the students through a discussion related to that week's lecture topic along with other related technical subjects.
- 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 3-4 student design teams on developing a solution to a loosely defined problem.

The details of the laboratory structure along with a discussion of the general evolution of the course can be can be reviewed in [7].

DESIGNING STUDENT TEAMS

Despite the fact that ENGR1500 is comprised of students from seven different engineering majors, organizing a realistic representation of an interdisciplinary design environment has proven to be challenging for first year students. This is compounded by the fact that the Wentworth Institute of Technology has also adopted a common first year engineering curriculum in the 2015/2016 academic year. As a result, there is little difference between students enrolled in the course, regardless of their chosen major.

To address the limitation in organizing student teams based solely on their chosen discipline, a skills-based approach is adopted for the semester long project component of the course. In order to facilitate this, students complete a student profile at the beginning of the semester. This profile worksheet is illustrated in Fig. 1.

Using the completed worksheets, the instructor assigns student teams in order to diversify the skillset of the team members. Based on prior experience with first year design projects, certain rules are in place to organize the teams; these are as follows:

1) A priority is placed on certain skills wherein an attempt is made to include at least one member per team that self-assessed a level of expertise of a 4 or 5. These skills are :
   - Manufacturing
   - Team management
   - Solidworks or other CAD software specified in 'Other_________'
   - Electronics
   - MATLAB or other programming experience specified in 'Other_________'
2) If the skills specified in 1) are met, an attempt is made to match pairs of commuter students with complementary skills into groups.
3) If the skills specified in 1) and 2) are met, an attempt is made to match female students with complementary skills into groups.
4) If all other rules are met, an attempt is made to diversify the engineering disciplines within the group.

Once teams are assigned, the student design teams begin the development of their semester long design project [7]. For this, they identify a loosely defined societal need and engage in the six-step design process described by G. Voland in [8]. At the conclusion of the semester, students present their designed solutions along with its evaluation at the First Year Design Showcase.

Wentworth Institute of Technology
College of Engineering and Technology
ENGR1500 Student profile

Name:____________________

Major:____________________

Commuter: Yes/No (circle one)

Expertise:

Topic	Level of expertise (Circle one: 5- Expert to 1-no exposure)
Research	1 2 3 4 5
Manufacturing	1 2 3 4 5
Team management	1 2 3 4 5
Solidworks	1 2 3 4 5
MATLAB	1 2 3 4 5
Electronics	1 2 3 4 5
Biomechanics	1 2 3 4 5
Technical Communications	1 2 3 4 5
Soil Mechanics	1 2 3 4 5
Other: _____________	1 2 3 4 5
Other: _____________	1 2 3 4 5
Other: _____________	1 2 3 4 5

FIGURE 1
Student profile worksheet

DATA COLLECTION

Throughout the semester, a direct assessment is performed for all students for the following outcomes and corresponding criteria through both indicator questions on select course quizzes and/or scoring performed by the course instructor using a set of predefined assessment rubrics:

- **Outcome**: 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 (Fig. 2)
  - *Criteria*: Ability to Identify Needs/Constraints
    Method: quiz
  - *Criteria*: Ability to Apply the Design Process
    Method: quiz
  - *Criteria*: Ability to Verify Designs
    Method: instructor scoring with rubric
- **Outcome**: Recognition of the need for and the ability to engage in life-long learning (Fig. 3)
  - *Criteria*: Recognition of the need for Life Long Learning.
    Method: instructor scoring with rubric

- *Criteria*: Ability to engage in Life Long Learning.
  Method: instructor scoring with rubric

Assessment is also performed by the students through peer evaluation of their group-mates for the following outcome:

- **Outcome**: The ability to function on multidisciplinary teams (Fig. 3)
  - *Criteria*: Ability to Collaborate
    Method: Peer assessment
  - *Criteria*: Ability to Fulfill Duties
    Method: Peer assessment

All direct assessments are normalized to indicate the percent of students with a satisfactory or greater performance.

At the conclusion of the semester, indirect assessment was performed though a survey that was conducted for the students to voluntarily self-assess their work and provide insight into their experience in the course.

RESULTS

Direct Assessment Results

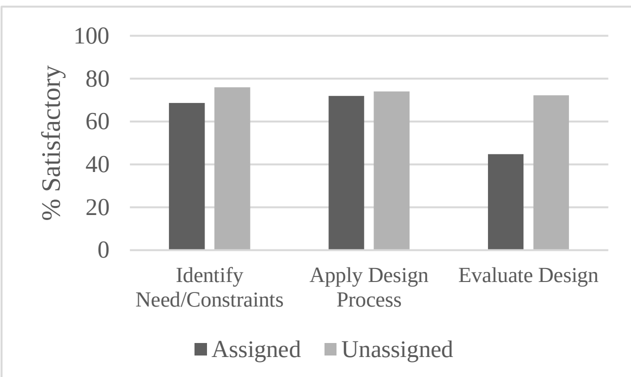

FIGURE 2
Assessment results for "Ability to design a system"

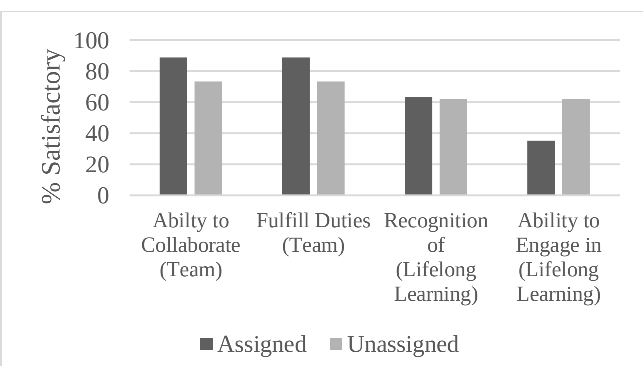

FIGURE 3
Assessment results for "Ability to work in interdisciplinary teams" and "Ability to recognize and engage in lifelong learning"

Due to limited adherence by course instructors to the specified rubrics for the unassigned groups, conclusions could not be drawn from the results in Fig. 2 and Fig. 3 for the unassigned students. Future studies must place increased emphasis on this standardization in order to draw meaningful conclusions

Student Survey Results

Students that engaged in the assigned group structure had two drastically different outlooks on the process. Examples of positive responses include:

> *"Though the interdisciplinary aspect of the lab groups were fun and allowed for different thought"*
> *"I really enjoyed being able to work in teams"*
> *"This was the best team I have ever worked with"*

The students that identified the experience in a positive light were, in general, in groups wherein all members took ownership of their component of the project and this is echoed in the positive results in the peer assessment results represented in Fig. 3. In most cases these groups produced very high quality designs. To contrast this, there were also a number of students that viewed the assigned groups in a negative light

> *"I didn't like that my teammates didn't do anything."*
> *"The course would be better if students got to pick their groups".*

In general, the students with a negative experience where either from groups that one, or more, member did not share equally in responsibilities or the member in charge of a system critical component was ineffective in developing their component. As a result these groups viewed the overall experience very negatively.

DISCUSSION AND FUTURE STUDIES

Judging by the overall attitude of the students towards the class, their projects and the overarching interdisciplinary, as reflected by the student survey answers, the option of assigning students to groups based on their skillsets, was a positive one. In addition, the high quality of the projects developed by these groups and the level of completion achieved by them is also a good qualitative measure of the positive effects that this practice had in the learning process. To build on this experience, in subsequent iterations of the course, the authors plan utilize an established team building system such as Team-Maker [9] in order to standardize the team construction process.

While the results as obtained from the voluntary self-reported survey display no significant differences between the groups, qualitative assessment of the students' presentations during the class-end showcase showed marked differences in both the solutions proposed and the level of completion achieved by the different student groups. Unfortunately we had not foreseen the need to perform a rubricated quantitative evaluation of the showcase presentations that could be used in place of/in addition to other forms of evaluation. Self-reported surveys are limited in reliability and in addition, by being voluntary, our assessment through this method results incomplete, possibly biased and non-representative. This observation, combined and contrasted with our qualitative evaluation during the students' showcase has prompted us to re-design the final assessment of this study for future iterations.

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