Work In Progress: Synthesizing design challenges to improve student effectiveness in first year engineering design courses

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Abstract -
Emulating the challenges of the professional engineering practice is often difficult to address in engineering education. In first year engineering design, students are often allowed opportunities to explore solutions while limited attention is paid to emulation design as experience from an industry practitioner. In order to address this deficiency, synthesized design challenges are integrated into a first-year engineering design course through a sudden design change while maintaining tight deadlines. The effectiveness of this approach is assessed by evaluating the quality of student design notes before and after the project-switch exercise. Student feedback is also solicited to allow for self-reflection and to assess the project’s plan for the design team that was temporarily assigned to their project. The authors hope to engage in a spirited discussion on employing similar methods to challenge students in first year design.

Index Terms – Design, Interdisciplinary, Student Experience

INTRODUCTION

Engineering Design is a common component of first-year engineering curricula. Along with the skills a student obtains though an engineering design course, it has been shown that the quality of the first-year design experience can also have significant implications regarding retention [1]. Various methods have been employed and studied to improve the overall effectiveness of the activities in design courses, including modifying the makeup of student design teams [2], integrating real world design problems, and employing student design competitions. However, the challenges and uncertainty of real-world practice are difficult to emulate in an academic exercise. In order to address this, synthesized design challenges are integrated into a first-year engineering design course, and the effectiveness of this preliminary exercise is studied in this work in progress.

FIRST YEAR DESIGN

The College of Engineering and Technology Wentworth Institute of Technology in Boston, MA is comprised of 7 Engineering majors for whom approximately 550 first-year engineering students enroll annually. Starting in 2015, the course Introduction to Engineering Design (ENGR1500) became a required course for all first-year engineering students as part of a common first-year curriculum. Each class section of this 4-credit course enrolls approximately 20 students in either discipline specific or mixed discipline sections. The sections utilized for this study involve two of the mixed discipline sections. In addition, details of the evolution of this course as well as the description of the current curriculum are described in [3].

In Introduction to Engineering Design at Wentworth Institute of Technology, all first-year engineering students work in teams of 3 to 4 students to develop a solution to a societal need that is identified and researched by the student team. Over approximately 8 weeks of the semester, students implement the 5-step design process [4] wherein in they formulate their design objectives, identify required functions and design constraints, propose realistic solutions, and implement and evaluate their solutions. Throughout this process, each student must maintain an individual design notebook that documents all aspects of their design development. This notebook details the student’s brainstorming processes, technical details, and overall design progress, particularly using iterative design methodology.

SYNTHESIZED CHALLENGE

The synthesized challenge to emulate uncertainty and change in project goals takes the form of a sudden modification to the design objectives and functions by reassigning teams to alternate projects. In approximately the fourth week of the project, all design notebooks are collected and provided to another team in the course. Students are told they are now in charge of this other project, and their own project will be completed by another team. Students must utilize the other team’s notes to propose a plan to implement and evaluate the design that is documented, as though they will complete it. Along with the proposed plan, students are also required to provide feedback on the quality of the design notes and indicate areas for which there are deficiencies. For this, each design team was required to address the following questions in a written assignment:

1) What alternatives were already explored and why were they discarded?
At the conclusion of the exercise (approximately one week), students are returned to their original project for the duration of the semester, possibly incorporating the feedback from the temporary team. This is meant to emulate a real-world workplace, where employees are often reassigned to new projects with little advanced notice. Similarly, employees often need to rely on the previous team members’ notes and documentation.

**ASSESSMENT PROCEDURE**

The effectiveness of this approach is assessed by evaluating the quality of student design notes before and after the project-switch exercise. For this, both investigating instructors collected the weekly notes from each student for the week immediately preceding the implementation of the design change as well as immediately after. These notes were then provided to the other involved instructor for evaluation.

The quality of the design notes before and after were assessed based on the following criteria: Formatting, Design Process, Completeness, and Appearance. The level of achievement for each student was done through a predefined rubric shown in Table 1.

Student feedback is also solicited to allow for self-reflection and to assess the projects plan for the design team that was temporarily assigned to their project.

**RESULTS**

Each instructor assigned a score for each criterion using Unsatisfactory = 1, Developing = 2, Satisfactory = 3, and Exemplary = 4. The overall change (Δ) for each criterion was calculated by subtracting the score from the notes preceding the activity from the notes following the activity for each student. The results of the overall change in student achievement is described in Figure 1. Here we see that the synthesized challenge had no meaningful impact on the quality of student notes for a large portion of students, as seen through the significant percentage of students with a Δ of 0. Although there was a minor increase in the level of achievement, based on the positive mean Δ, for Formatting, Design Process and Appearance, there was also a minor negative impact on the Completeness of the design.

![Table 1](image-url)

**Table 1:** Notebook Assessment Rubric

<table>
<thead>
<tr>
<th>Performance Criteria</th>
<th>Unsatisfactory 1</th>
<th>Developing 2</th>
<th>Satisfactory 3</th>
<th>Exemplary 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formatting</td>
<td>More than 2 required formatting elements disregarded throughout the entry.</td>
<td>Common formatting mistakes/oversight. At least one (no more than 2) element is formatted incorrectly or disregarded throughout the entry.</td>
<td>Infrequent formatting oversight or mistakes. All required elements are formatted correctly at least once in the entry.</td>
<td>All required elements are formatted correctly throughout the notebook entry.</td>
</tr>
<tr>
<td>Design Process</td>
<td>Notes Illustrate a complete lack of consideration for or awareness of the design process.</td>
<td>Notes illustrate minor considerations for at least one component of the design process.</td>
<td>Notes Illustrate meaningful considerations for the design process.</td>
<td>Notes Illustrate a proficiency in the use and implementation of the design process.</td>
</tr>
<tr>
<td>Completeness</td>
<td>Little to no usable content. A user would have to start the project over to move the project forward.</td>
<td>The notes are limited and a reader needs substantial assistance to understand the project and there is limited or no plans presented moving forward.</td>
<td>The notes illustrate sound descriptions of completed tasks but there is limited content for future project plans.</td>
<td>The notes demonstrate a clear and well documented description of the project that allows a reader to repeat and continue the project with minimal disruption.</td>
</tr>
<tr>
<td>Appearance</td>
<td>Poorly laid out and lack any discernable usable content.</td>
<td>Notes are poorly laid out, but do contain some figures and explanations. Difficult for a user to navigate and use.</td>
<td>Notes contain well laid out figures, data, and text but there are minor deficiencies that limit usability.</td>
<td>Notes are orderly, contain well laid out diagrams and figures, and is easy for a user to navigate and understand the content.</td>
</tr>
</tbody>
</table>

2) Do you agree with the decisions to discard these alternatives?  
3) What other alternatives did you think of?  
4) What was good about the previous team’s documentation?  
5) What was missing or insufficient given the previous team’s documentation?  
6) Could you complete the project as is given in the documentation?  
7) Thinking of your original project’s documentation, what do you think was good about it?  
8) Thinking of your original project’s documentation, what do you think was bad about it?  
9) Describe the current state of your original project (completeness, correctness, etc.).  
10) Describe the current state of the newly assigned project (completeness, correctness, etc.)
notes. Please see the Discussion section of this document for the rationale for this data.

The data generated from the written assignment provided additional insight into the effectiveness of this exercise. Overall, students were able to identify the deficiencies in others notes, and this often translated back to reassessing the quality of their own notes. For example, one student team reported, “We could have had a more detailed description of why we chose the design we did, and why we didn't go in another direction.” Students also effectively recognized when the prior team was exhibiting fixation on a particular solution without providing paper credence to other design pathways. Although this was not a focus of the study, it does illustrate that this exercise does provide students with additional insight into design concepts that can be difficult to instruct, such as the development of alternative solutions.

DISCUSSION AND FUTURE STUDIES

Although this study did provide the basic groundwork for future studies, the limited improvement exhibited through the quantitative analysis described in Fig. 1 must be discussed for institutions seeking to do similar initiatives. There are a number of factors that contributed to this data. These include:

Timing – Although the authors intended to initiate this activity immediately after students propose their alternative solutions in the third step of the five-step design process, a number of external factors caused the activity to occur later in the semester. This resulted in some student design teams being much closer to completing their project while others had significant work remaining. As a result, some of the higher achieving teams had very limited work illustrated in their design notebook after the study which resulted in a lower score in the post activity notes. It is recommended that for an effective implementation of this process, there must be significant design tasks remaining for all teams. Otherwise, the impact on student comprehension cannot be sufficiently realized.

High achieving students – Some of the students had very high-quality notes throughout the semester. As a result, a number of these students achieved the highest score in the assessment which left no room for improvement. These students either achieved a Δ of 0 or experienced a −Δ for those groups that had limited design work remaining after the activity. To address this, the authors plan to readdress the process of evaluation to account for students in similar stages of their designs.

Formatting and Appearance – Overall, the highest scores occurred in both formatting and appearance of the design notes. Since it was easy for students to comprehend these criteria, it is recommended that, in subsequent studies, added emphasis be placed on methods to improve understanding of the design process and how to formulate a complete documentation of design activities.

Going forward, the authors plan to continue to use synthesized design challenges to improve the quality and effectiveness of project based design courses. Taking into consideration timing and the evaluation procedure, the authors plan to reevaluate this process and provide recommendations for institutions seeking to employ similar activities in their first-year curricula.

CONCLUSION

The process of synthesized design challenges provides potential opportunities in first year design courses. Through challenging students and forcing them to reevaluate their own work, a tactile understanding of concepts like the development of alternative solutions can be realized. Although the implementation in this study only identified minor improvements, there is promise in this approach. Future studies will readdress this process and identify the potential of similar approaches being used in first year engineering education.

REFERENCES


