Familiarity with the Engineering Design Process

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Abstract

Familiarity of, followed by competency with, the engineering design process is a goal of every undergraduate engineering program. The aim of the current work is to craft a series of assignments that lead the students through a design project from start to (near) finish on a very simple concept so that the engineering design process can be the focus of the exercise, not the results of the process. This paper will outline the ongoing attempts to give first semester seniors a comprehensive, team based design experience which should help students succeed in their capstone projects. A brief historical overview of the program and the perceived issues will be discussed. Three years of successive implementations of this engineering design process experience will be presented along with end of semester results. Finally, a look forward to how the exercises may fit into the curriculum long term.

Keywords

engineering design process, group project

Background

Process! If one word can sum up engineering education, process would surely be on the shortlist. Engineers have a process for everything and engineering educators use process to teach students some valuable lessons. Homework formatting to the mature student is recognized as a problem solving process. The engineering design process is not different. To the accomplished learner, it is a clear pathway from an idea to a reality. However, to the inexperienced, it is a roadmap written in a foreign language, poorly photocopied many times over with a huge coffee stain on one side. In other words, unintelligible.

Over a period of 7 years, this engineering educator and colleagues at the same institution began to notice a disturbing trend in seniors enrolled in their capstone design course: a lack of familiarity with the fundamental concepts of the engineering design process. This process takes many forms as described by different authors, but always involves the same ideas: recognize a need, gather information, restate the problem in objectifiable terms, generate possible solutions, use objective terms to remove unworkable solutions, choose the best remaining solution and calculate design details. The problem observed in seniors in their final engineering project was that, though they might be able to recite a standard form of the engineering design process, they were unable to apply it to the task presented to them (or chosen by them) in their capstone project. Clearly, a change was needed and this educator began a quest for a simple implementable solution.

Idea

To begin, the curriculum was examined to determine where a student would have gained experience with the engineering design process. This lead to a startling discovery. While the Introduction to Engineering course in the first semester of the freshmen year contained significant design process content, very little, if any, experiences had been included in subsequent semesters. That is not to say that all content through six semesters was devoid of all design. The occasional "design" problem was included in Thermodynamics, or Dynamics of Machinery, or Heat Transfer. However, in most of these situations, the students were only working with a part of a design, that is to say, most of the significant decisions had already been made. These exercises only required the student to make one or two decisions based on a few complicated calculations. Occasionally, the students did need to perform some basic research to understand the problem a little better, but it was not a start to finish design problem. Usually, this was because the principles under study were very complicated and the students were to busy struggling with understanding the nitty gritty implications of Newton's Laws of Motion or other such concepts to spend time on understanding how to distill background research into a goal statement.

This idea was reinforced while teaching an introductory programming course for the first time. Too often educators are trying to teach more than one thing at the same time. Giving a novice programmer the task of writing a program to solve a problem from an engineering course they are currently taking is double dipping in a way that does not serve the student. Too often, design can be taught the same way. The conclusion drawn by the author was that some start to finish engineering design process experience was needed where the focus could be on the process itself, not the product of that process. To that end, a semester long, team based design project was created and added to a first semester senior level required course. It should be noted that the small size of the institution only allows engineering courses to be taught once per year.

Implementation

The first task was to either find or develop a model for the project. In a book by Eide et al.[1], a project for freshmen engineering students was presented that was a great starting point. It described a sample assignment for freshmen engineering students to increase awareness of the engineering design process through a team based project. It seemed an excellent model to follow.

The second task was to find a statement of the engineering design process that was of appropriate detail for seniors. Robert Norton's books on Dynamics of Machinery[2] and Machine Design are both used in the curriculum and they contain a very good statement of the engineering design process.

1. Identification of Need
2. Background Research
3. Goal Statement
4. Task Specification
5. Synthesis
6. Analysis
7. Selection
8. Detailed Design
9. Prototyping
10. Production

This statement was chosen as the basis for the exercise with the implicit iteration of any engineering design process stated throughout the project. The overall project for the course was broken into 5 parts:

1. Project 1 - Steps 1 - 4 - understand/gather/state/objectify
2. Project 2 - Step 5 - brainstorm ideas
3. Project 3 - Step 6 - use constraints to rule out unworkable designs
4. Project 4 - Step 7 - use criteria and decision matrix to choose final design
5. Project 5 - Step 8 - perform detailed design calculations and produce drawings

Formal statements of each project were written as a guide for the students. Groups were allowed approximately two weeks for each project. Each project submission required a report on that specific step which was graded and returned with comments. Groups were then allowed to make corrections and resubmit Projects 1-4 for regrading along with Project 5. In this way, iteration was introduced into the process and the students could see their work change over time as their understanding of their particular problem and of the engineering design process increased. With each phase, students were reminded that the engineering design process, not the results of the process, were the focus of the assignment. None of the projects, in any of the three years required or encouraged students to fabricate and test their designs because there simply was not enough time. Fabrication and prototyping would also tend to shift the focus from the process to the product.

Year 1 - Fall 2016

- Goals for year 1: Initial trial. Determine whether exercise is truly needed.
- Projects: Corn silk remover, fingernail trimming catcher, paint can pourer, residential wall socket improvement, twist off jar top assist – all taken from Eide[1].
- Observations from year 1: Students demonstrated a lack of understanding on how process flows from need to product. Visual communication emerged as primary deficiency for all groups.

Year 2 - Fall 2017

- Goals for year 2: Increase emphasis on visual communication from previous year. Improve direction given to groups in visual communication.
- Projects: Stranded motorist SOS device, door opener device, residential drain clog removal tool – all taken from Eide[1]. Drink and snack holder for gaming table, waterless handwashing station for developing world – all developed by author.
- Changes from year 1: Reword assignments to focus on visual communication.
- Observations from year 2: Students cannot translate assignment statements into rubrics without help. Visual communication still a major issue.

Year 3 - Fall 2018

- Goals for year 3: More clearly communicate project intent to students and continued focus on visual communication.

- Projects: Concrete mixing tool for developing world, pipe cutting tool for developing world, financial planning software tool, campus transit plan, pedestrian crossing plan from commuter parking lot – all developed by author.
- Changes from year 2: Report grading rubrics developed and distributed to students for each phase. CATME introduced as per evaluation tool. Trying projects that are less mechanical engineering centric and forcing students to think bigger.
- Observations from year 3: Project choices posed big problems for mechanical engineering students as most were outside what they viewed as their role. Most were unsure how to being the project.

Observation

After three course offerings where this experience was assigned, the following observations have been made based upon student comments and student work:

- The students initially dislike project. They see the object of their design work to be of little value because they believe that it is too simple.
- Confusion abounds in the initial phases of the project. The students have just been through two or three semesters of heavy theoretical training so this seems too easy. They just want to know what calculations they need to perform.
- Initial quality of work is very poor. Most students are unable to tie the steps of the engineering design process together to create a coherent narrative. Most groups do not understand how to use visual communication tools effectively.
- After a few submissions, quality of work begins to rise quickly. Intelligent students catch on and the rest follow suit. Whether they see any value in the assignment or not, they still learn what they should do.
- At the completion of the project, the quality of work has increased significantly. Most of the submissions bear little resemblance to the original work.
- At the completion of each of the three course offerings where this assignment was included in the course, an informal discussion is held with the students to obtain their feedback on the assignments. Most students indicate an increase in their understanding of the engineering design process but indicate that they would have preferred to gain this understanding in some way that involved less work and writing. A few students find the entire exercise to be a great value. A few other students indicate that they still see little value in the exercise. A formal survey before and after the assignment would be a valuable tool for future iterations through this exercise.

Future Work

The following changes are planned for Fall 2019:

- Pre and post surveys on familiarity of engineering design process will be given to students to measure the change in their understanding.

- Pre and post surveys on the value of the assignment will be given to students to measure their perception of whether the assignment contributed to their understanding.
- No more software design projects. However, process design and conceptual oriented projects seem to work well.

References

1 Eide, Arvid, and Jenison, Roland, and Mashaw, Lane, and Northrup, Larry, Introduction to Engineering Design, McGraw-Hill, Boston, 1998, p 72.
2 Norton, Robert, Design of Machinery 4th Edition, McGraw-Hill, Boston, 2008, p 7.

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