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Design Projects Concurrent with Capstone Design

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ABSTRACT

Nearly all Mechanical Engineering programs have a capstone design experience. In many curricula, there is a classroom component that complements the capstone course. This paper presents a novel approach to that "complementary" class – one in which students are asked to complete two design projects concurrently with ongoing work on their capstone project.

Some context must be provided in order to understand the motivation for this approach. First, at a small private Midwest university, the capstone projects are two-semester projects. In addition, each student group works on a different project. Some of those projects are composed of only mechanical engineering students, but the majority of groups include students from another department.

There are four major reasons for the approach described in this paper:

1) Redesign is a critical part of the design process, and is covered in the course. However, since most students do not start prototype development until spring semester, redesign cannot be readily exercised and evaluated in the fall.
2) Similarly, the course projects allow students to demonstrate a testing and validation plan. This plan must be executed, and performance compared to expectations. The difference between the actual result and the expected result must then be explained and may lead to further redesign.
3) Because of the wide range of capstone projects, some students have limited exposure to identifying customer needs in their capstone projects – particularly projects related to national competitions, or where an industry sponsor already has a complete job specification. Having an ambiguous project description requires all student teams to demonstrate the ability to carefully define the design problem, including customer needs, constraints, and criteria.
4) Having gone through all of these steps a first time, it is hoped that the quality of the senior design projects improves.

While students clearly learn from this process, they generally do not like this. Student evaluations have shown that they feel they have too much "project work" between this course and capstone. In addition, students often complain that topics such as testing and validation and redesign are "common sense", though evaluation of their performance often indicates that students cannot do this with a high degree of proficiency.

The paper will describe the course projects, further describe the context and motivation, and provide student feedback including survey results. The hope is to present a model which other schools can consider as they work to get more design into the curriculum and improve the quality of the capstone experience.

BACKGROUND

This paper describes work completed at Ohio Northern University (ONU), a small, private, comprehensive university focused on undergraduate education. At ONU, engineering students are heavily involved in design projects. There are a series of projects in the freshman year [1], a dynamics project in the second year [2], mechanism and clutch design projects in the junior year, as well as a year-long capstone project in the senior year. While the students are starting work on their senior capstone project, they concurrently take a course entitled “Process of Design”. This format of lectures accompanying the capstone process is not unique [3]. This course is required for all students.

As stated in [3], there are a wide variety of structured and methodologies in capstone courses. The capstone projects at ONU are two-semester projects, with the “Process of Design” course only in the fall semester. Students are typically expected to complete a working prototype of their capstone design before the end of the spring semester. Projects vary widely from industry-sponsored projects, to national competitions, to student-suggested new product development.

The purpose of this paper is to discuss what we believe to be a novel portion of the Process of Design course. Students in this course are asked to complete two projects during the course – these projects are concurrent with their capstone projects. In general, this is done for two reasons. First, the design course features desired outcomes that are not typically addressed by all of the capstone projects. Second, the design course can help students avoid pitfalls typically encountered in the second semester of the capstone project. By having to complete an additional course-based project start-to-finish, these pitfalls can be avoided.

Ohio Northern University is a member of the Kern Engineering Entrepreneurship Network (KEEN) [4]. As such, students are expected to demonstrate the entrepreneurial mindset [5]. Yet because many of the capstone projects are already defined for the students, they do not have the opportunity to fully demonstrate this mindset. By providing other projects during the course, students can demonstrate and be assessed on these aspects of the entrepreneurial mindset. Note that the emphasis on entrepreneurial mindset does not imply that all students are being taught to create new business ventures; rather, this mindset consists of an enterprising attitude, multidimensional problem solving, productive collaboration, illuminating communication, and resolute integrity.

Secondly, testing, redesign, and reconciling theory and experiments often cause problems for students late in their capstone projects. By having already completed a start-to-finish project which requires testing and redesign, we feel students will be better prepared when they encounter the need for this in their capstone project.

PROJECT DESCRIPTIONS

In taking this approach, it was decided to focus on areas that students typically do not consider during their capstone project – and certainly not in the first semester of their capstone project. As such, the projects were designed to give them experience on two very different parts of the design process. An overview of each project is given here.

The first project focused completely on the “problem finding” aspect of design. This is typically something that is not at all a part of the capstone design process, since at most institutions students are presented with a problem to work on. Their capstone process then becomes deciding how to solve that problem. While this mimics many industrial projects, it is also worth noting that creative, empathetic engineers are often able to find WHAT they should be working on, rather than just how to solve it [6]. Yet there is very little in the traditional engineering curriculum to train our students to think in this way.

Students were challenged to keep “bug lists” [7]. This exercise asks students to individually track all of the things that “bug” them for a given amount of time. They are to track these as possible areas for new products or services. The exercise is often used in classes focusing on creativity or entrepreneurship. Next, students were randomly assigned to teams. Random assignments were chosen rather than other team-selection methodologies [8] for simplicity, and to get students working in multiple teams concurrently. This forces students to work with a variety of students, not only with their friends or their capstone team. This is part of a broader effort to instill the entrepreneurial mindset in all of our engineering students.

Student teams were to discuss the lists they had come up with, consider other options, and settle on three possible problems. They were then asked to survey others, including non-engineers, about why they thought this was a good problem. While not formally trained in survey design, they were asked to use the principles of surveying outlined in [9].

The feedback they received was used, along with other criteria (the team’s ability to deliver a solution, and the team’s own opinion) to select one of the problems. Next, they had to show how they applied the design process to proposing a solution to that problem. They also needed to go back to potential customers and see what they thought of the proposed solutions.

The second project focused on the need to consider testing and validation in design, the value of redesign, and the use of limited materials. Students used a question-answer period with the faculty member to define the problem, which essentially consisted of designing an offset hanger to support a conveyor in a factory. The load was to be 400 lbs with a safety factor of two. A rough geometric sketch was provided to describe the relative position of the conveyor and hangar obstacle. Students were told that the testing would have to be completed on their prototype using an Instron™ tensile tester. It was the responsibility of students to consider how the part should be attached to the Instron, and how to define success. Students were allowed to use one of several types of materials provided in the shop, including any scrap, or purchase their own materials. Students were told that safety, weight, and cost were the criteria on which the design would be evaluated.

SURVEYS

End-of-semester surveys for this 30-student course included some questions directly related to these two projects. A summary of these results will be included here. Responses were based on a 5-point Likert scale ranging from strongly agree to strongly disagree. On the problem-finding project, 15 of the 27 students (56%) agreed or strongly agreed that "the project helped me think about finding problems in everyday life", with 7 more students neutral. 18 of the 27 (67%) agreed or strongly agreed that "the project helped me think about customer feedback in design", with 5 neutral. On the second project (which involved building and testing), 13 of the students (48%) agreed or strongly agreed that "the project helped me think about testing as part of design", with 8 neutral. 16 of the 27 (59%) agreed or strongly agreed that "the project helped me think about redesign", with 5 neutral. This is an early indication that students felt the goals were accomplished. This survey was repeated in the second year of the course, the data from both years is summarized below.

Question	Year 1 (n=27)		Year 2 (n=35)	
	% strongly agree/agree	% neutral or better	% strongly agree/agree	% neutral or better
Customer feedback	67	85	69	83
Finding Problems	56	81	63	91
Testing	48	78	71	94
Redesign	59	78	54	86

Although the data set is small, it seems the projects were generally more effective at their goals the second year. The authors believe this is because the instructor was more intentional about tying those themes from the course to the project.

LESSONS LEARNED

Although the evidence is self-reported and anecdotal, some important things have been learned this year, and over several years of running similar projects. It is hoped that other programs considering similar projects can learn from these findings.

First, it is important to note that students do not like this. They feel the idea of having multiple projects going on at the same time is unfair, and takes away from their ability to do well on their capstone projects. They also often feel it is unfair to have to be working with two different teams simultaneously (one team for their capstone project, one for their course project). This is an issue worth considering, as approximately 50% of our students are involved in other major activities on campus (varsity sports, band, theater, etc.) which place restrictions on their time. If Ohio Northern University were not primarily a traditional, residential campus, this might not be possible.

Second, proper selection of projects is very important. Students must be able to complete the objectives without an unreasonable amount of time so that it does not adversely affect their other courses. Proper testing facilities should be available to students throughout the project so that they can learn to operate them, measure attachment points, etc. Materials and shop facilities must also be made available if prototypes will be required. And certainly the projects must be carefully aligned with the desired outcomes.

Third, many students struggle to accurately assess the causes for the difference between their theoretical results and what they find during testing. Taking time in class to reflect on the possible causes is important. For example, we have found that often the students do the analysis correctly, but fail to take into account that there is statistical variation is material properties such as yield strength. Finally, students have to be reminded that computer tools (such as Finite Element Analysis) are good, powerful tools – but that they should not be trusted blindly – they still rely on assumptions, and require that the user properly describes the geometry and material, and properly applies the loads.

Finally, much of the content of this course used to be in the junior year. However, students complained that there was too much time between the introduction of this content and their capstone projects. As such, the course was moved into the senior year to be concurrent with capstone during a recent curriculum revision.

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