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Implementation of a Flotation Platform Project for a First-Year Engineering, Project-Based Course

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Implementation of a Flotation Platform Project for a First-Year Engineering, Project Based Course

This paper describes evidence based approach to update a first-year engineering course project to meet more educational best practices. In fall 2014 and fall 2015, the first-year engineering course at a medium-sized, Midwestern, private university implemented a new design project in the first-year engineering course sequence. Learning objectives for the project include introducing the engineering design process, working with uncertainty in the design process, and improving teaming/communication skills. In this project, students were tasked with designing a platform that could support three specified loads with additional requirements for the height of floats that could be submerged under each condition. The students had several weeks to determine a design based solely on simple modelling equations and the explicit loading and size requirements. They additionally had to consider the implicit requirements of the system, including stability of the structure, waterproofing, and appearance. Student groups exploited computational tools for their design by creating an engineering drawing in Creo Parametric for visualization and by developing equations and an expected performance plot in Microsoft EXCEL for analyzing their system. Finally, they were able to build and demonstrate their platforms using course purchased construction materials which included: poster board, shipping tape, plastic wrap, aluminum foil, and a handful of other similar products. Some positive traits of the project include:

(1) The modelling equations are simple and do not require physics or calculus knowledge to design the system, so they are appropriate for first-semester students. However, finding a solution to the project is not trivial for a first-year student.
(2) The design requirements can be structured to allow for many different designs or more highly constrained to force an outcome of more specific designs.
(3) The cost of materials needed for the project is relatively low and all materials are easily obtained. The project could easily be changed by simply changing the allowable materials for construction.

In both implementations, students were asked to write a short reflection on the skills acquired after completing the project. Reflections were categorized based on reflection themes to determine common themes and trends. This assessment, while largely qualitative in nature, provides a snapshot of how well students internalize the learning objectives for the project. Results from 2014 indicate that student participation in the project is beneficial to their understanding of the physics relationships specific to the project, their comfort in using of engineering tools (most notably CAD software), and their ability and comfort in working in group projects While 2015 data was similar, more students indicated that they enhanced their understanding of the engineering design process through the project. The paper will detail some speculations for why these differences were seen.

Introduction

Many first-year engineering courses around the country are focused on using project-based learning and early design experiences: both identified as best practices in education (1, 2).

Research has shown that inductive teaching methods, where students are presented with a challenge and then learn methods to meet the challenge, inspire students to deeper mastery of the material (3). Additionally, active learning techniques, such as project-based learning have been shown to help increase student retention (4) and the formation of engineering identity (5). Research has found that creating cooperative projects with positive societal implications can be a positive attribute especially for underrepresented groups like women and minorities (6,7).

First-year courses are also ideally suited to introduce the concept of design, a trademark feature of engineering practice (8). While many schools still focus on design experiences only in senior capstone classes, more and more universities are including a design project within their first-year experience (9). This gives students an opening to understanding engineering early in their academic career and can provide a meaningful touchstone during future engineering course work. With collaborative, project based design in mind, the University of Notre Dame developed a new project for its first-year engineering course sequence. First and foremost, the project was intended to increase student exposure to design through a hands-on experience. In addition, the project was created for the first-semester, where students would be concurrently in calculus and chemistry (physics is not taken until second semester). Therefore, the focus should be on a simple model that allowed for exploration throughout the design space. This paper will detail the development of this project and describe initial feedback from its offering in 2014 and 2015.

Course/Project Background

The University of Notre Dame is a suburban, private, research university in the Midwest serving ~8,000 undergraduate students. Most students at the university are traditional college age (18-22 years old), full time students, and live on campus. The College of Engineering consists of nearly 1,700 students (first-year through senior year) at the university and has been steadily increasing over the last 5 years. The College of Engineering is approximately 30% women and 22% minority student population.

An introductory engineering two semester course sequence is taught to all engineering intents during their first-year at Notre Dame. For both the Fall 2014 and Fall 2015 semesters approximately 550 students completed the fall semester of the course sequence, with approximately 90% of those students persisting to the second semester course. For both academic years, the students attended two 75 minute course meetings each week in a section of 43-47 students. Most classes were interactive in nature, with a combination of lecture time and hands-on activities throughout the 75 minutes.

The course is structured around two modules, each containing a group project as the main deliverable. Course content was focused on understanding general engineering principles by completing these multi-week projects, specifically focused on understanding the Engineering Design Process. While the structure of course meetings and locations has changed over the years, the course has used project-based learning as a staple for 14 years. New projects are continually developed for the course to replace older projects that need improvement or have just become stale after being used for many years. Therefore, the development and implementation of the Platform Project were not unique occurrences for the course. In both 2014 and 2015 the same two projects were used: (1) a Lego Robotics project and (2) a flotation platform project (delivered for the first time in fall 2014). In 2014 the robotics project was presented first, but the project order was switched in 2015.

The flotation platform project is the focus of this paper, wherein groups of 4-6 students designed, built, and tested a platform that could float under three loading conditions. The number of students in a group was set such that a maximum number of 9 groups were in each section, a requirement due to presentation and testing time requirements, but a smaller group could effectively complete this project as well. The project was developed to meet several important criteria: low cost, simple mathematical model, and permits many creative solutions. In addition, the overall learning objectives of the project included introducing the following concepts:

(1) Following an engineering design process
(2) Using a mathematical model to make design decisions
(3) Creating a visual representation using Computer Aided Design (CAD)
(4) Understanding uncertainty in design (factor of safety considerations)
(5) Presenting data in graphical form (Excel)
(6) Presenting the design through appropriate technical writing

Importantly, students were required to complete the entire project design and build without any testing allowed until the day of their demonstration. Therefore, groups were forced to understand the background equations and trust their calculations to support the loading conditions – a significantly unsettling prospect for first-year students. However, this was countered by using a simple design equation. With just a simple understanding of buoyancy and volume calculations for various shapes, students could explore a wide variety of flotation scenarios. This allowed course staff to spend minimal time on the background science and maximum time on how to make design decisions.

Students were first tasked with creating a flotation platform that could support three loading conditions: unloaded, nominal, and limit loads. The exact weights of each of the three loading conditions for each year are summarized in Table 1 below and were changed for each year. In each case, the loads were added to the installed weight of the group's build.

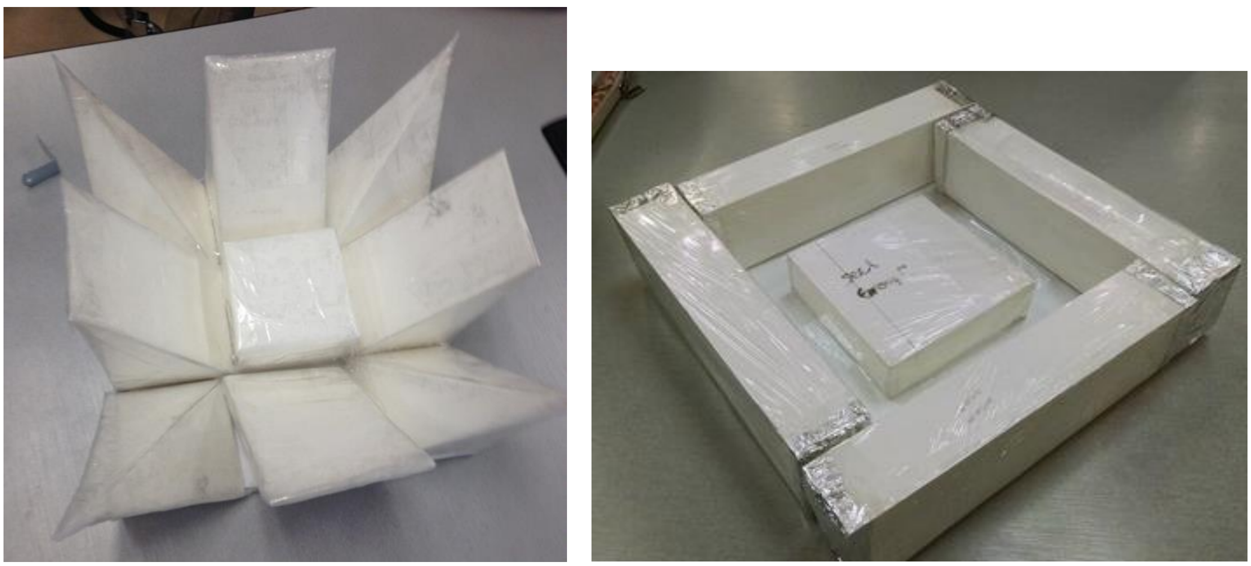
Table 1. Weight Added to the Flotation Platform for each Loading Case

	2014	**2015**
Unloaded Case	0 N	0 N
Nominal Case	10 N	10 N
Limit Case	20 N	30 N
% Change Req.	Less than 70%	140 – 160%

In addition to the 3 loading conditions, there was an additional requirement of how much the platform could sink between loading conditions (called % Change Req. in Table 1). This requirement stated that the change in depth from nominal to limit loading case must be a certain percent (% change required) of the change in depth from the unloaded to the nominal loading case. This requirement was included to increase the complexity of the designs. Students were required to either create shapes with a changing cross sectional area or use multiple shapes to meet the percent change.

After students contemplated designs, they created theoretical plots to determine the appropriateness of their design. This included considering possible errors and how these would affect the performance of the system. Next, the students created engineering drawings of their design using the computer aided design software PTC Creo. While the CAD component of the project teaches a useful skill for engineers, it is an add-on to the project and not explicitly required to complete the project.

Finally, students were given supplies to create their project and time to build before testing. Examples of final student projects from each year are shown in Figure 1 below.



(a) (b)

Figure 1. Examples of student designs created in (a) 2014 and (b) 2015.

The project took place over a 7 week period (outlined in Table 2). Throughout each week, the engineering design process was a constant theme and lessons were focused on matching steps in the design process. In addition, groups were required to turn in intermediate design proposals and group review memos before the final project was due.

Table 2. Project Timeline over 7 weeks of the course

DATE	COURSE CONCEPT	STEP IN ENGINEERING DESIGN PROCESS
Week 1	Describe design and constraints of the project	Needs Assessment
Week 2	Scientific Principles Introduced In-class buoyancy Activity	Problem Formulation

Week 3	Basic understanding of stability Representing Theoretical and Experimental Data in Excel	Abstraction and Synthesis
Week 4	Error and Robustness Considerations Introduce Mechanical Drawings	Analysis
Week 5	Create visual representation in PTC Creo (Computer-Aided Design)	Analysis/Implementation
Week 6	Discussion of technical writing Students complete project	Implementation
Week 7	Test Final Design Complete technical paper	Implementation

In addition, the project could easily include a societal connection. In 2014, the project was given only loose connections to real-life applications through lectures, including oil drilling platforms, cargo ships, and off-shore wind farms. However, in 2015 a more explicit customer, Verde Industries, was invented with a specific need for a flotation platform for an offshore wind turbine farm. Due to the general nature of the project, many customers and uses could be created for a flotation system with a set of requirements. Therefore, this project can be adapted and used for many years.

The materials for the project can be changed due to cost considerations or to change the expectations of the project build. All groups were given a 12 inch x 12 inch piece of foam board to build all of their floats on. Students were limited to poster board, various types of tape, aluminum foil, plastic wrap, marbles, and string as building supplies. This keeps the recurring costs for the project very low and could be further reduced by using recycled materials. In addition, there were several one-time costs associated with the project. Thirty HDPE boards were purchased to act as the installed weight of the customer's platform, five plastic bins were purchased as testing stations, and a set of verified weights are needed to act as the various loading conditions. In addition, groups were offered K'Nex kits as building material (these were already owned by the course and not a new cost), but very few chose this option. Additional materials that were considered but not provided during these offerings included popsicle sticks, foam, and Lego sets.

Methods

The data source for this study was student reflections written for a class assignment at the end of the project. The reflections were collected through an electronic portfolio which is a regular part of the course assignments. The assignment required that students answer a prompt (shown below) and include at least one picture of their finalized project. While the prompts were similar in nature, the prompt was refined in 2015.

Prompt for 2014

At a minimum, you should add a picture of your platform with a short description and a summary of the skills acquired from the project. You can add greatly to this, however, and make it a more meaningful/interactive space

Prompt for 2015

If a potential employer were to ask you about what you did and learned through this project experience, what would you say?

Although these are graded assignments, they are graded largely on a complete/incomplete basis and are only a small part of the participation grade for the course. Therefore, if students completed the assignment and turned it in as instructed, they would receive full credit. After the completion of the semester, the reflections were reviewed by course staff and coded for thematic elements. Students were not aware that this question would be used for educational research purposes.

Fall 2014 and 2015 had 542 and 558 students enrolled, respectively. In each year, 3 out of the 12 course sections were semi-randomly selected to be studied. Although the sections were selected by random draw, the three sections were checked to ensure that they were from three different instructors to reduce the chance of one instructor biasing the student results. In total, 117 students in 2014 and 129 students from 2015 were studied.

The students' responses were grouped into 13 categories and tallied. The categories are detailed below with description and an example from the text. Responses could receive any number of the categorical descriptions.

Table 3. Coding for Student Reflections

CATEGORY	DESCRIPTION	EXAMPLE
Math/Science	Grasp equations needed for completion of the project	"In terms of technical skills and knowledge, I learned about Archimedes' principal"
Overcoming Adversity	Persevered despite issues and challenges in the project work	"The final and most important thing that I learned from this project was never to be afraid of failing, and to learn from where you fail."
Computer Aided Design (CAD)	Learned how to use the CAD package PTC Creo	"learning how to utilize computer software to aid design, as I did during this project, is an important engineering skill"
Design Process	Applied the engineering design process outlined in class	"For one, the design process made a lot more sense once we were able to actually try it for ourselves."
Uncertainty	Considering error and uncertainty in design calculations	"That was one of my main takeaways. Robustness of design is a huge factor because there will always be one minute influence that

		could cause a design to fail if it is not robust."
Time Management	Better understood how to manage their time	"Working on the project allowed me to learn how to schedule my time more effectively."
Group Work	Expanded skills necessary to work effectively in a group	"The main [thing] I learned from this project was the skill of communication and of compromise."
Technical Communication	Created appropriate technical documents, such as plots, drawings, memos and reports	"I learned how to properly write an engineering design report, and communicate this information effectively."
Engineering Disciplines	Clarified a specific engineering discipline (generally civil engineering)	"It also taught me a lot about the different responsibilities of structural and environmental engineers"
Managing Tradeoffs	Considered tradeoffs between customer requirements, costs, or safety or mentioned optimization	"It shows us that when completing projects there are many tradeoffs that we are going to have to make decisions on in order to fulfill the project."
Project Description Only	Did not state specific material learned. Included only a description of the project.	N/A
Construction Techniques	Understood best method for constructing and/or waterproofing floats.	"I learned how to construct structurally sound floats using rudimentary materials and keep them as waterproof as possible."
Customer Needs	Learned to take customer needs into consideration for design	"By doing this project, we learned…how to design a product that meets the customer's specifications."

Results and Discussion

Coding from the student reflections are presented in Table 4. In 2014 and 2015, student reflections were coded for an average of 2.5 and 2.3 categories, respectively. In addition to a summary of the overall class, reflections were also broken down by gender. In both years, the gender of the student had no discernable effect on the lessons considered (based on chi-square test). This is an important note that the project concepts did not appear to have an explicitly "gendered" scope.

Table 4. Percent of students who responded with each category per year. The top 3 categories are shaded.

Coded Lessons	2014			2015		
	ALL	Men	Women	ALL	Men	Women
Math/Science	54%	54%	53%	45%	42.5%	50%
Overcoming Adversity	8%	9%	6%	16%	18.4%	9.5%
Computer Aided Design	46%	47%	44%	19%	19.5%	16.7%
Design Process	24%	26%	19%	41%	44.8%	33.3%
Uncertainty	21%	20%	25%	20%	19.5%	21.4%
Time Management	1%	1%	0%	5%	4.6%	7.1%
Group Work	38%	38%	36%	59%	63.2%	50%
Technical Writing	16%	16%	17%	9%	8%	9.5%
Engineering Disciplines	2%	2%	0%	3%	3.4%	2.4%
Managing Tradeoffs	14%	11%	19%	3%	3.4%	2.4%
Project Description	19%	17%	22%	10%	6.9%	17%
Construction Techniques	5%	5%	6%	2%	3.4%	0%
Customer Needs	1%	1%	0%	2%	2.3%	0%

In 2014, the top lessons learned were Math/Science, Computer Aided Design, and Group Work. In comparison, 2015 lessons learned were Math/Science, Design Process, and Group Work. While 2 categories remained the same, there was a remarkable difference in the number of students who reported understanding the design process as a major lesson learned. This may be attributed to several course related factors. First, in 2015 the project was introduced along with the initial introduction of the engineering design process, possibly making a greater connection between this specific project and the design process. In addition, the project material was refined in 2015 to include more explicit connections to steps of the design process. Each lecture in 2015 started by summarizing which part of the design process was being practiced that day.

Collectively, we interpret the results of this analysis to show that that the project meets many of the stated objectives:

(1) Following an engineering design process

In both years, students selected understanding the engineering design process as an important aspect of the project. However, the evidence suggests that continual reminders and connections to the design process can aide in these associations.

(2) Using a mathematical model to make design decisions

Understanding the physics and mathematical model was a main takeaway. Because students were not allowed to test their designs before demonstration day, they were forced to use relationships instead of a simple guess and check method. Many students reported anxiety with this method of design. It's important to note that while the equations governing this design problem are fairly simple, the combination and consideration of all possibilities are quite complex for a first-year student. Many students reported struggling with how to work through the theory and make decisions.

(3) Creating a visual representation using Computer Aided Design (CAD)

The introduction of computer aided design was a secondary objective for this project. Many students noted this new skill as an important engineering skill. This project introduced CAD over only one week of the project, but this could easily be expanded.

(4) Understanding uncertainty in design (factor of safety considerations)

Dealing with uncertainty is one of the newest concepts for the students to understand. In both years, ~20% of students described learning to work with uncertainty as an important component of the project.

(5) Presenting data in graphical form (Excel)
(6) Presenting the design through appropriate technical writing

Objectives 5 and 6 were both captured in the Technical Writing category. In many cases, students described specific writings, graphs, and presentations in their development. While mentioned, this may need to be expanded in scope to better emphasize the importance of writing and describing their design decisions.

In addition, learning to work in groups was a consistent theme. While this was not originally written as an explicit objective, course faculty fully expected that a group project would also foster collaboration skills. Many students reported a significant difference in expectations between high school projects and this project. This was especially apparent in 2015, when this was the first project that students completed. In 2014, students had a group experience through the robotic pet project before starting this and fewer wrote about the group experience.

Finally, students presented a generally positive view of the project and the material they learned. Many students specifically noted how their knowledge from the projects helped them to develop their engineering identity. A few representative examples are shown below.

I started this project having little knowledge of the concepts, and I was unsure of how this would be accomplished. However, I grew as the project went on, and I was able to help my group complete a successful float.

I think that is what separates an engineer from a college student who knows math and science. We don't just know how to solve problems. We know how to come together, as a team, to solve problems quickly and efficiently. We meet deadlines, cut costs and share as much information as we can. This project taught me how to approach problem solving in the real world.

I have to say throughout this project working on it and going through the lectures in class I managed to learn a lot about team work and the principles that are related to floating and buoyancy and most importantly the engineering design process. I feel more confident in my choice of engineering as a major.

Conclusions

This project is presented as a possible model for creating a rigorous design experience from a fairly simplistic model. The project is also designed to have a low overall cost and is tunable from year to year to allow for a longer lifetime of the general project. By using a meaningful background for the project, it can even serve to show the societal impacts of engineering. Finally, it allows for significant creativity on the part of the student groups. In each offering of the project, there were many different designs that were created and successful.

The results of this analysis show that the project effectively meets the learning goals in the minds of students including understanding the engineering design process, using math and science for design, and working effectively with a team. However, it is worth noting that the project introduction through course lecture plays a vital role in students' views. The study is currently limited due to its exclusive basis on student reflective exercises. While these responses provide a strong connection to student thought process, they do not offer a measure of student learning. Future work includes an analysis of gains in student knowledge across the semester using designed assessments. Furthermore, overall course objectives should be considered across both projects in the semester to clarify how all course activities can be optimized to meet student needs.

References

1. Frank, M., Lavy, I., and Elata, D., Implementing the Project-Based Learning Approach in an Academic Engineering Course. Journal of International Journal of Technology and Design Education (2003), Volume 13, No. 3, pp. 273-288.
2. Millis, J. and Treagust, D. ENGINEERING EDUCATION – IS PROBLEMBASED OR PROJECT-BASED LEARNING THE ANSWER? Australian Journal of Engineering Education (2003), pp. 2-16.
3. Prince, M. and Felder, R., The Many Faces of Inductive Teaching and Learning. Journal of College Science Teaching (2007), Volume 36, No 5, pp. 14 – 20.
4. Kvam, P. The Effects of Active Learning Methods on Student Retention in Engineering Statistics. The American Statistician, Vol. 54, No. 2. (May, 2000), pp. 136-140
5. Du, X.Y., Gendered practices of constructing an engineering identity in a problem-based learning environment. European Journal of Engineering Education (2006), Volume 31, No 1, pp. 35 – 42.
6. Burke, R. and Mattis, M. Women and Minorities in Science, Technology, Engineering, and Mathematics: Upping the Numbers. Edward Elgar Publishing, 2007.
7. Farrell, E. Engineering a Warmer Welcome for Female Students: The Discipline Tries to Stress its Social Relevance, an Important Factor for Many Women. Chronicle Higher Education. 2002, February 22.

8. Dym, C., Agogino, A., Eris, O., Frey, D., Leifer, L., Engineering Design Thinking, Teaching, and Learning. Journal of Engineering Education (2005), Vol. 94, No. 1, pp. 103-120.
9. Dym, C., Learning Engineering: Design, Languages, and Experiences. Journal of Engineering Education (1999), Vol. 88, No. 2, pp. 145-148.