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Engagement in Practice: A Second Year Project-Based Learning Sequence

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Introduction

Sophomore year can be a challenge for many undergraduate engineering students. Introductory courses from the freshman year transition into the core science- and math-based foundation courses that will lead to more specialized courses in later years. It is here that students sometimes lose focus and cannot see that they are still headed to the career or specialization that sparked their interest. They forget why they chose engineering in the first place, and so retention can be a challenge. This paper will present a course that not only addresses this issue, but also incorporates project-based learning and community involvement to enrich the education experience.

Background

Inarguably, engineering is a challenging curriculum. STEM fields have a completion rate ranging from 21-54% as opposed to business at 63-71% [1]. In addition to academic challenges, notably in math [2], students need motivation and perseverance. Motivation in particular can be highly effective, and it was shown that getting students to work on a “fun” project increased the one-year retention at Penn State University up to 98% [3]. Though there are many examples of first-year projects, there are notably fewer instances of second-year projects found in the literature.

Another tactic that can increase retention is the development of learning communities of students that continue from the freshman year to graduation [4]. The development of community among students aids in their ability to complete their degrees. Furthermore, career mentoring by faculty during the second year has been shown to increase retention in the sciences as well [5]. Taking it a step further, connecting students to their future is also very important during the second year [6]. These aspects are also incorporated into the course described here and discussed later.

Curriculum

Florida Polytechnic University is a state university that opened in 2014. The Department of Mechanical Engineering restructured the curriculum in 2017. An overall goal of the new program was to incorporate a design course into all eight major semesters of the students’ engineering education experience from freshman to senior year. The freshman engineering design courses, as at most universities, introduce basic concepts of engineering and provide an overview of engineering. Skills needed for successful engineering teamwork are introduced. Within the sophomore year, those skills are built upon and practiced further. The overall curriculum then includes hands-on courses that focus on engineering laboratories in the third year. The final year consists of traditional capstone design projects, similar to those at most accredited programs.

As noted in the previous section, retention can be improved by many different factors. One of the results of having a project course with professional skills every semester during the entire degree program is that as students work in teams and present so that they get to know each other well and develop a community. As already noted, a community aids in student retention throughout the entire four-year sequence [4]. Particularly in the second year, more benefit is gained when a focus is placed on directing students toward their future careers and providing mentorship to aid their motivation to continue in the program [6].

This remainder of this paper focuses on the sophomore-level engineering program that was developed and consisted of a sequence of two courses. As noted, this course was designed to bridge the gap between the freshman engineering design courses and the junior year laboratory courses.

Educational goals for the second-year sequence included reinforcing and building upon professional skills introduced during the freshman year. This included teamwork, team writing [7], and presentation techniques. Relevant technical skills were also introduced in the course. As this was for a mechanical engineering program, computer-aided drafting (CAD), best practices for intuitive mechanical design [8], and prototype construction skills were introduced. The first semester focused on additive manufacturing techniques, while the second focused on subtractive manufacturing and the use of a machine shop.

Student retention via engagement was another major course goal that was intentionally incorporated. To help remind students why they want to become engineers and keep them interested, real-world projects were given to student teams. This connected students to their future careers in a palpable way. In each semester, students were given both an individual project and a team project. These four projects throughout the year were the focal points in which both professional and technical skills learned were practiced and reinforced. The individual project focused more on the technical skills while the team project focused more on professional skills, though both types of projects incorporated a mixture of skill demonstration.

The team projects, which involved real-world, community-based projects are discussed in further detail here. This next section will outline the projects during both years, with a following section focusing on the lessons learned.

The Community-Based Projects

The sophomore course sequence had two main team projects during the year, one in the fall and another in the spring semester. This course sequence was taught in this method for two years, with different projects each year and slight variations in the way projects were managed. Lessons were learned in the implementation of the first year that led to improvements in the second cohort that are described below.

During the first implementation of the course sequence, students designed a project in the first semester and then prototyped it during the second semester. This mimics the way a year-long capstone project is managed. For this first cohort, a collaborate effort was arranged with the local school district to have the second-year engineering students design and develop adaptive solutions for specially-abled students in the K-12 exceptional education schools.

The need for adaptive solutions can be found in nearly all communities, as each specially-abled child tends to have unique abilities and needs that are not necessarily well met by the one-size-fits-most commercially-available products. Customization for each child provides greater benefit to both the child and caregivers, but typically comes at a high cost due to wages for design and labor. University students developing these adaptations, however, can provide customization benefits to children and the community at a materials-only cost, while also gaining valuable design and teamwork experience. Examples of customizations that were made by engineering students include extensions for utensils and writing implements, extension and simplification mechanisms for toys and games, and specialized tablet and assistive electronic device mounts and holders.

During the initial semester, engineering students were able to tour an exceptional education facility and see first-hand the challenges students and teachers faced. Since only a few of the engineering students were able to travel, those who did go reported back to the rest of the class. Teams were then formed randomly, and each team identified a problem found in the educational center and brainstormed solutions. Initial designs were made in CAD and presented to the entire class for feedback before the semester ended. The second semester focused on honing the designs based on the feedback, implementing these solutions as prototypes, and presenting them to their peers as well as teachers from the education facility.

During the second implementation of the course the following year, the cohort had two different team projects, one per semester. For the fall semester, students again tackled adaptive projects for the local schools. However, they were given the directive to focus on smaller items so that the project could be completed within the semester. Inspiration for this was taken from the project making "Happy Meal" toys at Duke University [9]. Students were asked to adapt a small toy or game, or develop a completely new game, for specific disabilities. There were still a wide range of projects produced despite the limitations. Musical instruments, card games, board games, and carnival games were adapted for blindness or physical impairments. One team developed a completely novel board game as well.

For the spring semester of the second cohort, a different project assignment was prepared. Community organizations and local cities partnered with the course and provided specifications for green walls that they wanted to implement to help beautify areas, in addition to educating the community in sustainable practices or providing fresh produce. The locations of these proposed green walls included a famous local attraction, a city park, and a public library. There were three different sections of the course that semester, so each section was assigned one of these locations in which to focus. The section was divided into several student teams. These teams developed concepts on paper based on specifics provided by their assigned community organization. After some design iteration, the teams translated their ideas to CAD. The concepts were realized via scaled 3D printed models. At the conclusion of the semester, each team pitched their design to the manager in charge of their assigned community project. This was done during class final presentations. The CAD and scale models helped to showcase their concepts and facilitate communication and visualization with the non-technical community managers. The focus of the technical work in the projects was on overall creative designs implemented with CAD, designing based on intuitive feasibility, and some research into sustainable technology and practices. The details on full implementation of these projects, such as mounting and loading, were not required as most students had not yet completed the necessary coursework to do this. However, some advanced students included basic calculations and analysis and shared this with the class during their presentation.

Lessons Learned

Implementing a program like this of course had many challenges. Some are those are common to any project-based course, but specifics for these projects are noted here. There were some issues, however, that were particular to the types of projects selected and the limitations of sophomore-level skills that need to be considered by anyone considering a similar program.

The first issue is finding collaborative partners. This is not as simple as arranging projects for a capstone sequence. Due to the students only being at the sophomore level, they generally have not developed many of the technical skills needed to have a high probability of success. In fact, allowing the students to make mistakes and learn from the failures was something that this early project allowed and encouraged. Allowing failure also allowed for more creativity [10]. All of this helped to reinforce the goal of making a positive impact on student satisfaction in the engineering curriculum and ultimately retention.

For this specific project, a clear goal was first developed. In both the first cohort and first project of the second cohort, this was to develop custom adaptations of items for specially-abled children. One reason this was chosen both because adaptations could be mechanically focused and suited to the mechanical engineering audience. (It is noted that electrical programs can easily adopt projects that involve adding large electrical switches or conveniences to toys, and software programs can make apps to ease learning or caregiver tasks.) A second reason for selecting this project was that there was a genuine local need where student ingenuity could make a difference and the number of projects could be scaled and continued indefinitely. Finally, service-based projects are particularly useful for engaging and retaining female students [11].

With this clear goal, targeting specific local partners was the next step. Local education centers were called until a personal connection was established. It was a challenge navigating the school system, but perseverance paid off. In this case, the county school district was thrilled with the project idea and an administrator became a direct liaison. This partnership was ideal in that the potential recipients being part of an education organization, the administrators and teachers understood that the projects were a learning opportunity for the engineering students and that there was still value in the endeavor even if not all projects would be successful. The value of students gaining real-world experience at the sophomore level was mutually accepted. It is also suggested to those considering such projects to call specialty centers, assistive-focused organization, and physical therapy centers for collaborations. This is because these have a much smaller administrative force to navigate and can also reach children not in school or even adults.

The second challenge then became maintaining the collaborations, which is common to nearly all partnerships. As such, this was in mind even before the collaboration was finalized. When speaking with potential collaborators, the expected outcomes were made clear. As previously noted, the sophomore level of the engineering students means that many implemented designs are expected to fail. The only way to mitigate this is to find collaborate partners that fully understand and accept that no successful outcome is guaranteed. In this case, working with an educational institution with the shared goal of educating students permitted this condition. Regular communication kept the collaboration going.

A third challenge is another one faced with all projects – cost. In this instance, starting a collaboration with a public school did not allow for funding by the recipient. Even if partnering with a company or therapy center, cost issues have an extra challenge because usable final products are not guaranteed. Careful negotiation and considerations need to be made. For this implementation of adaptive technology, an internal grant from the university was used. To stay within a very narrow budget, students were restricted to common off-the-shelf and generic materials such as PVC pipe, basic lumber, basic hardware, glue, Velcro, tape, magnets, and 3D printing. Basic tools were provided to make simple cuts and holes to the material. These limitations were announced after an initial round of brainstorming so that students could first unleash their full creativity, and then experience the real-world need to adjust concepts to meet manufacturing reality and budgets. Limiting materials and resources proved to be very effective in keeping cost and material requirements low.

Time is another common project challenge and was it no exception here. During the first cohort, students were given a full year to design and implement their projects. While there were some very good projects facilitated by the extra time to redesign and build, it was hard to manage all of the projects during second semester. This was because both semesters had three sections of students taking the course at different times, and students did not typically register for the same course section as their fall teammates when enrolling in the spring. In addition, some students started becoming bored with the project as the simpler designs did not have many aspects to hone and construct. The projects were simply not as complex as those given during a capstone experience. At the sophomore level, a shorter time period was more beneficial. This observation is based on the experience of the second cohort. The second cohort was given the same project, but with a narrowed scope. This helped to reduce the time needed to go through the entire design cycle. It also helped to maintain student focus on the tasks and project. Having a different project the following semester refreshed creativity and also gave students an experience working with a completely different team. In addition, providing a second design cycle nearly immediately after the first allowed students to make improvements based upon their previous experience, which will hopefully further enhance student performance in future projects.

The final issue noted was that of design feedback. While the projects certainly provided real-world interaction and skills development, students did not always gain feedback from the users. Semester timing made it such that the recipients of the projects received the items just as the engineering course was ending. In addition, many projects were not suitable for distribution to children and so feedback was limited to analysis of the failures and limitations. While this failure feedback has great value, some students were disheartened that they could not see their work immediately benefit a child. As a solution, it is suggested to allow post-semester access to optionally design and construct a second prototype under faculty or staff supervision. The use of a closed-group social media platform or e-mail list may be a means to send students photos, video, or other updates from the recipients so that they can get feedback on how their designs or projects were received and used by the community after the course.

Discussion

No analytical data was taken from this course due to an IRB not being available. In addition, the sequence was only conducted twice, so the exact effect on student retention cannot yet be provided. However, some observations were made that could be of use to others considering similar projects.

Overall, students generally responded positively to the course both in personal comments and in end-of-semester evaluations. The real-world project brought definite interest and a bit of challenge that would not have otherwise been present in a more closed project or textbook examples. In fact, most students jumped in eager to have real projects to put on their resumes and into their portfolios. Students viewed this early real experience as a means to help them gain an advantage to get their required internship during the remainder of their engineering studies. Many students also noted that they could clearly see the connection of the skills they were learning in their courses to how it related to their future career engineering in the real world.

Women especially found the addition of real-world projects engaging, as was expected. Some of the female students were so inspired that they personally delivered their items to the education facility in order to ensure they saw the initial reaction from the recipients.

Conclusion

This paper presents some initial work in bringing real-world projects to lower classmen. While there were successes observed subjectively, there is certainly more work that can be done to improve a program like this. However, numerous challenges were overcome over the two years and it is hoped that ideas and advice here can be used to start similar programs at other institutions. The projects and concepts can be adapted scaled to meet different student levels, programs, and courses. It is hoped that this starts a dialog to consider adopting carefully curated community collaborative projects from the start of engineering education programs and on throughout, rather than only at the end.

References

1. N.W. Klingbeil, R.E. Mercer, K.S. Rattan, M. L. Raymer, and D.B. Reynolds, “Rethinking engineering mathematics education: A model for increased retention, motivation and success in Engineering,” in *Proceedings of the 2004 American Society for Engineering Education Annual Conference and Exposition*, paper 2465, 2004.
2. S. Cai and W. Grebski, “Improving retention through implementation of ‘toy fun’ projects into fundamental engineering classes,” in *Proceedings of the 2011 IAJC-ASEE International Conference*, Paper 104, Eng 103, 2011.
3. S. Cai and Y. Zhao, “Design project based modules to promote engineering learning and retention,” *The Technology Interface International Journal*, Vol 11(1), 2010.
4. K. Ricks, J. Richardson, H. Stern, R. Taylor, R. Taylor, “An engineering learning community to promote retention and graduation of at-risk engineering students,” *American Journal of Engineering Education*, Vol 4(2), 2014.

5. B. W-L. Packard, “Mentoring and retention in college science: Reflections on the sophomore year,” *Journal of College Student Retention*, Vol 6(3), pp. 289-300, 2004.
6. L. Schreiner, “Linking student satisfaction and retention,” *Noel-Levitz,* pp. 1-16, 2009.
7. J. Wolfe, *Team Writing: a guide to working in groups*, Bedford/St. Martin’s, 2010.
8. J. G. Skakoon, *Detailed Mechanical Design: a practical guide*, ASME Press, 2000.
9. Duke University, “Fun in a box: Happy meal challenge teaches first-year students design thinking,” Pratt School of Engineering News, April 20, 2017.
10. S. Phillips, K. Giesinger, R. Al-Hammoud, S. Walbridge, and C. Carroll, “Enhancing student learning by providing a failure risk-free environment and experiential learning opportunities,” *Proceedings of the 2018 American Society for Engineering Education Annual Conference and Exposition*, Paper ID 22665, 2018.
11. M-E. Reyes, K. Powell, M. Aronson, and J. Goldberg, “Mentoring and community service for recruitment and retention of women in science and engineering at the University of Arizona,” *Women in Engineering ProActive Network Conference*, 2003.