

Intercollegiate Student Design Projects: Lessons Learned by Four Universities

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Abstract

Four Universities (Baylor University, University of Dayton, University of Detroit Mercy and Villanova University) have piloted a series of collaborative intercollegiate senior design projects where students from different schools collaborate on senior projects. Nearly a dozen projects were undertaken over two years. The level of collaboration for different projects varied from working together to create a single prototype to working independently to build multiple prototypes. A number of lessons were learned including the value of having periodic face-to-face (non video) meetings. Also, project complexity seems to have a positive effect on the collaboration while simple projects enabled the teams to abandon communication and build independent prototypes. In all, collaborative design projects proved to be highly valuable from the student perspective although not free of frustrations. Faculty also observed the pedagogical value of collaborative projects but there was no consensus as to if or how much extra work is required to administer them.

1- Introduction

Capstone design projects, being the culminating experience of a typical four year engineering curriculum, present an opportunity to reinforce a number of critical soft skills that are deemed important in professional engineering practice. Such soft skills are outlined by the Engineering Criteria of ABET¹ relating to communications, teamwork, ethical responsibilities, contextual understanding, among others. A more extensive list of student outcomes, presented by the Kern Entrepreneurship Education Network (KEEN), is aimed at fostering an entrepreneurial mindset in graduating engineers.²

The learning outcomes reinforced by the capstone design projects cannot be divorced from the context of the course itself. For example, a course in which engineering students from a single discipline working on a discipline-specific project would prove difficult to satisfy and properly assess the learning outcome *an ability to function on multidisciplinary teams* (ABET outcome d¹). The work outlined in this article was borne out of a search for a better context for the capstone design experience. The search for a better context in which to naturally foster an entrepreneurial mindset in engineering students led the authors to propose the intercollegiate (the term intercollegiate is intended to mean multi-university) design project.

Intercollegiate design projects can be classified as either competitions or collaborations. The history of intercollegiate capstone design projects reveals that the vast majority are competitions. One good example is the SAE Collegiate Design Series (<http://students.sae.org/cds/>) which attract thousands of engineering students from hundreds of universities. A far less common type of intercollegiate project is collaboration between two or more universities.³⁻⁷

Four Universities (Baylor University, University of Dayton, University of Detroit Mercy and Villanova University) have piloted a series of collaborative intercollegiate senior design projects where students from different schools collaborate on senior projects. Each project team is made

up of groups of students from multiple universities. This paper starts by making an argument for collaborative design projects in terms of student outcomes. It then describes the course structure, particularly as it relates to collaborative team meetings. Three projects are described with lessons learned, followed by evaluations and lessons learned.

2- The arguments for collaborative projects

The focus is on collaborative intercollegiate design projects. The authors argue that such projects provide an excellent context for instilling the entrepreneurial mindset, by requiring communication, teamwork, system-level thinking, and intense customer focus.

2.1- Communication

Functioning successfully in a collaborative project team made up of groups of students from multiple universities requires sophisticated communication. In a geographically distributed team, communication needs to be very productive. Students have limited, if any, in-person meeting times and virtual meetings are fairly restrictive. Collaborative teams also require the resourceful use of all available means of communication. As for graphical communications, collaborative projects mandate highly accurate technical documentation of concepts and designs.

In contrast, communication between competition teams is often not beneficial to the team sharing the information, and when it does happen it is generally driven by a sense of sportsmanship.

2.2- Teamwork

Collaborative projects require effective teamwork abilities as the members of the team are made up of mostly new acquaintances. The members from the respective individual universities consist of students who likely know each other fairly well, but the teamwork skills needed to engage with team members from the other universities is significant. Also, multi-university teams require a high level of maturity in order to keep the interactions collaborative and not competitive. It is fairly easy for interactions to degenerate into a competition which is very harmful to the chances of success of the team. Collaborative projects also require great wisdom to resolve the inevitable conflicts that will arise during the course of the project.

2.3- System-level thinking

Intercollegiate collaborative projects require system-level thinking to cascade the design requirements into various subsystems that can be worked on by the various groups. In a sense, they require an ability to see and communicate the big picture view while also mandating a meticulous attention to details in design, documentation, and manufacturing.

On the requirement for system-level thinking, it is not obvious whether there is a difference between collaborative and competitive projects.

2.4- Intense customer focus

Unlike the majority of competition-based intercollegiate design projects, collaborative projects tend to be either sponsored by an industry partner or have a particular client such as a person with disability. This context with a third-party customer is very important for nurturing an entrepreneurial mindset in engineering students because the aim is less on winning the competition and more on satisfying and pleasing this customer.

3- Objectives

The objectives of this study were to:

- determine whether there is discernible added value to the entrepreneurially-directed educational experience of engineering students and whether such added value is commensurate with any added complexity and faculty workload.
- ascertain the sustainability of this type of project beyond the availability of outside funding.

4- Course structure

Figure 1 shows the course structure from the perspective of the meeting requirements.

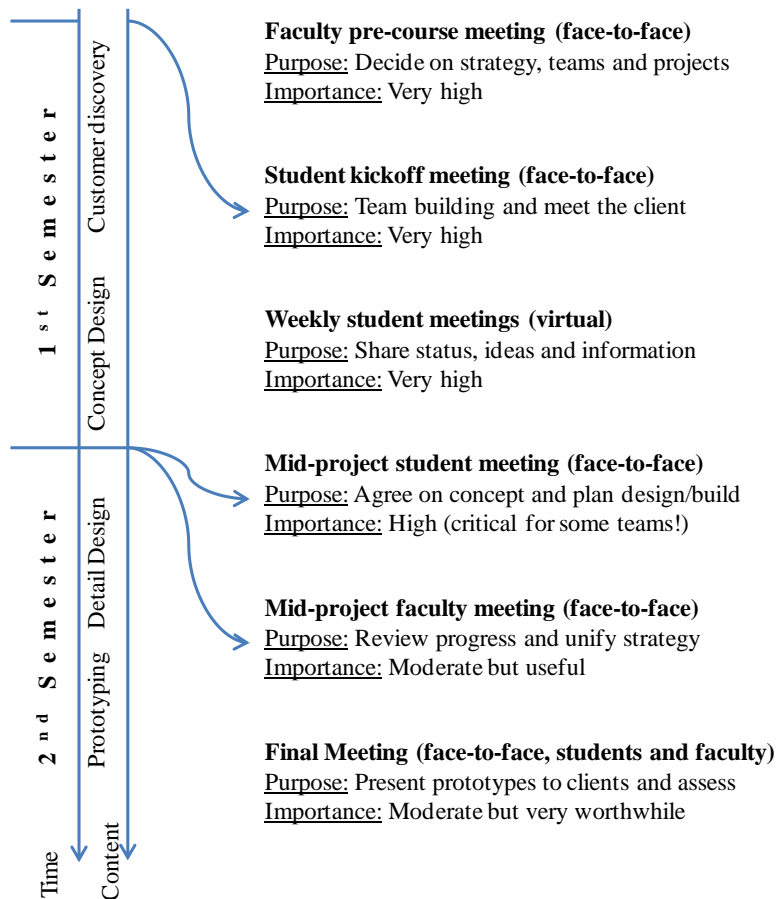


Figure 1 – Course structure relating to meetings (both faculty and students).

The projects were completed in a two semester course sequence and followed the standard design process starting with customer discovery followed by concept generation, detail design, and prototyping. The collaboration required a number of face-to-face (non video) meetings as well as weekly virtual meetings. The faculty met before the start of the course to decide on the projects, and then met halfway through the course sequence to evaluate the status of the teams and projects and to determine the strategy for the second half. The students were brought together in a kickoff meeting that proved extremely valuable for team formation. Some teams were brought together again after the first semester in order to agree on a concept and divide the design and prototyping work. Finally, students and faculty got together at the end to wrap up the prototyping and deliver their prototypes to the client.

5- Sample Projects

This section describes three projects featuring three different outcomes relating to collaboration. All three projects are judged successful from the product outcome point of view, but with varied success from the collaboration standpoint.

5.1- Medical Bed with Integrated Commode

The client for this project is a quadriplegic individual (disabled veteran) who does not have a colostomy bag and, as a result, tends to periodically defecate in bed. Two groups from two different universities were tasked with developing a solution to help the client avoid this situation. The student mix consisted of mechanical engineering and nursing students from University of Detroit Mercy. The second group, from Baylor University, consisted of mechanical engineering and electrical engineering students. All students self-selected into the groups. The students from the nursing school were primarily in charge of managing patient relations.

The two groups collaborated closely through the final prototyping. One group constructed a custom-built bed that transforms into a chair, shown in Figure 2. The other group created an automated system that removes a section of the bed (the hole shown in Figure 2) and replaces it with a bedpan. The automated bedpan system was designed to interface with the bed both geometrically and functionally. In this case, the two subsystems are critical to the functioning of the device.

The collaboration extended into the final prototyping phases and benefitted from strong communication, teamwork, and conflict resolution skills. The complexity of the project required a high degree of system-level thinking. In a number of ways, the complexity of the project ensured that the two groups collaborated since neither had the budget nor the human resources to build a complete system independently of the other group.

It is important to note that the critical phase of this collaboration occurred at the midpoint where the two groups had to agree on a common path forward. In general, this phase is rife with danger as far as the collaboration is concerned and forcing the two groups to agree on a unified concept can destroy the team. It is this possibility that the face-to-face mid-project student and faculty meetings (see Figure 1) are intended to mitigate.



Figure 2 – Students describing to a news camera their prototype bed with a built-in commode designed for use by a quadriplegic client.

5.2- Pressure Sore Mitigation

The client is a disabled veteran who is paralyzed from the chest down as a result of a gunshot wound. He suffers from repeated pressure sores as a result of sitting for prolonged periods of time. Two groups from two universities were tasked with developing a solution to help him avoid future pressure sores. As in the project in section 5.1, the team consisted of mechanical engineering and nursing students from University of Detroit Mercy and mechanical and electrical engineering students from Baylor University. All students have self-selected into the project.



Figure 3 – Students posing for a picture with their client (sitting) after presenting him with a device that will help him not get pressure ulcers.

The teams collaborated on customer discovery and concept generation, then decided on a solution with two complementary but independent subsystems: 1) A pneumatically adjustable pad that periodically varies the pressure on the skin; and 2) An automatic reminder system that tracks the sitting time and prompts the user for action. The team is shown in Figure 3 at the time of delivering the prototype to their client.

By most measures, this collaboration was very successful as it resulted in a novel and useful technology that could yield great benefit to the disabled community. The team collaborated extensively at the beginning and shared resources and information as they developed concepts and ideas. However, having agreed on a path forward that allowed them to work somewhat independently, communication tapered significantly and was nearly non-existing near the end.

5.3- Customized Walker System

The client for this project is a disabled veteran with spinal cord disorder that weakens his arms and legs and causes significant back pain during walking. Three groups from three different universities were tasked with developing a solution for this person's unique needs. The makeup of the students consisted of mechanical and electrical engineering students from Villanova University and Baylor University and mechanical and nursing students from University of Detroit Mercy.

The teams collaborated on customer discovery and concept generation but could not agree to integrate the design and produce a single prototype. Therefore, three replicate prototypes were built. Figure 4 shows the client trying out one of the prototypes presented to him.

The team being made up of three different groups had many difficulties with communication and conflict resolution, and stopped being a team at the midpoint of the two-semester course sequence. The decision to cease communication and disband as a team was precipitated by two factors. The first is that three-way collaboration proved more difficult, with many more failure modes than two-way collaboration. The second is that the project was of such a limited complexity and scale that the respective groups felt they had the resources and time to build independent prototypes. On the upside, redundant prototyping allowed for investigation of various ideas and technologies and ultimately led to a successful product.



Figure 4 – Students presenting their client with a customizable walker and training him on its proper use.

6- Evaluation

The evaluation consisted of interviews with the students, instructors, and support staff, as well as general observations. A pre- and post-survey of mindset is under way and will be presented in future articles.

6.1- Student Feedback

Students overwhelmingly indicated that the collaborative intercollegiate design experience is valuable for their job search. “That’s all they wanted to talk about” said one student who just went through a job interview, referring to the interviewers’ strong interest in the intercollegiate project.

Students indicated a high level of frustration with initial communication of customer needs and feedback. With the client in proximity to one school, a situation arose where one group had access to first-hand customer information and feedback while the other groups had to rely on second-hand information which was not always comprehensive or timely.

Students indicated the need for more face-to-face interactions. Students from various schools seem to only know the names of students that they met face-to-face. Since the four schools involved are fairly distant from each other, the kickoff meeting could not always involve all the students. Students that did not attend the kickoff meeting remained somewhat unknown to the groups from the other schools. This is an argument to limit such collaboration to schools within driving distance of each other.

Students described current tools for virtual collaborations (video conferencing) as insufficient for the task of bringing groups together. Meetings are limited in time and only one person at a time can be on camera and speaking.

6.2- Faculty Feedback

There is little consensus on if and how much extra work is involved in managing these projects, with responses ranging from “no extra work” to a “2+ multiplier.”

Forcing the students from various schools to agree on a single concept can lead to catastrophic breakup of the team.

6.3- General Observations

Intercollegiate projects seemed to attract female team members at much higher proportions, although it is likely that other factors are involved such as the social dimensions of the projects. This is the subject of future investigation.

More complex, system-level projects force collaboration between groups, while simpler ones allowed teams to avoid the needed compromises. Collaboration and communication existed as

long as they were deemed necessary by the teams. Once a team decided to pursue different concepts, the collaboration was reduced dramatically and communication all but ceased.

7- Conclusions

About a dozen intercollegiate design projects have been undertaken by the four member schools. The success rate, as far as collaboration, was fairly high at 75%. The effect of these projects on the entrepreneurial mindset of the students is still being evaluated. However, the value to the students who have taken part in these projects is found to be high. Intercollegiate projects have proven demanding on the faculty and expensive to operate. Frequent face-to-face contact will help alleviate much of the strain on the faculty. Conducting these projects in schools within the general geographic location (driving distance) will allow more face-to-face interaction and will make them more sustainable from a financial point of view.

8- Acknowledgment

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