

A Method to Provide Student Peer Mentorship within the Capstone Experience

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Abstract— While students entering the capstone course are eager to apply their technical skills, the open-ended nature of the experience can represent a barrier to success. Well-formed planning, communication and intra-team skills are often differentiating elements among the most successful project teams. The abstract nature of these professional competencies requires a contextual basis to effectively develop within a higher cognitive domain. To this end, our capstone course has adopted a platform that offers students the freedom to choose a project sponsor that aligns with their own professional skills or desired learning environment. In a typical cohort we offer a mixture of industry sponsors (small to medium size local companies, emerging startups and established industry leaders) and faculty sponsors developing projects tied to their on-going research. Students have attributed this latitude in sponsor environment, character and style to their success in the course and transition to a professional career. This work offers an extension of this approach to include projects sponsored and managed by post capstone students. Students interested in an entrepreneurial-based experience tend to select this project and cite the nature of the mentorship as a driver for their decision. A template describing the method is presented for potential implementation. In addition, reflections from the capstone students illustrating the impact of this experience on their professional careers are included.

Keywords—capstone; peer mentorship; student leadership

I. INTRODUCTION

The capstone experience provides a singular mechanism in undergraduate engineering education. Unlike other courses, the capstone offers the student an opportunity practice their problem solving skills in the context of an industry-driven prompt. For many students, this may be their first exposure to an environment requiring an open-ended, and often multi-disciplinary, approach to a project with realistic design constraints. While this setting serves as a platform for the integration of technical knowledge, the experiential nature often exposes the importance of leveraging “soft” professional skills; as well-formed planning, communication and team skills are often differentiating elements among the most successful project teams [1]. The balance of technical skills with these professional competencies can be viewed through the lens of the competing requirements associated with the product verses process discussion [2,3].

While it is the responsibility of the capstone instructor to provide guidance and clear learning objectives, the mentorship offered by the project sponsor is often the primary shaping element. Internal faculty and industrial partners represent the most common forms of project sponsorship. The relative merits and adopted role of industry and academic project mentorship has been discussed in the literature [3-6]. It has been noted that projects initiated by faculty can enhance student exposure to the process of design whereby industry-sponsored projects tend to focus on overall product quality [2]. This work examines the impact peer-to-peer mentorship on the tension between process and product drivers by offering a peer-based structure to project sponsorship.

The form of capstone mentorship often influences project trajectory and outcomes. Our program allows students to self-select their program sponsor. This latitude allows the student to match their career goals to the character and style of their adopted project sponsor. Students seeking to gain exposure in to a research-oriented or process-centric project typically request a project with a faculty sponsor. Students involved with industry sponsors often view the “real-world” roots of their project as a positive attribute [4-7]. Beyond contextual impact, interaction with an industry mentor provides exposure to the role of professional competencies in a project life cycle. Specifically, surveyed students have cited, awareness of the benefits of strong communication skills, the importance of technical writing and project management as professional skills modeled by their industry sponsors [8-10]. While both the academic and industry based models provide a framework of opportunity for students to cultivate technical and professional skills, some students often finds the experience within these models limiting. Students in this category are seeking to explore the limits of their skill set with an entrepreneurial dimension.

The principle of ownership is defining element within the student capstone experience. Apart from the discussion of process and product, the magnitude of engagement and commitment from the student team itself is often the primary driver for success. It may be self-evident to state that students exhibiting a high-degree of initiative, drive and self reliance often yield successful capstone projects; however, crafting an environment that cultivates these characteristics across a broad

range of students it not obvious. The discussion of student ownership in learning begins early in the education process [11]. Upon reaching their senior year, students have become proficient at completing assignments and realizing the learning objectives established by course instructors. Success within this structured and guided environment does not always translate to the open-ended environment of the capstone. Variation in ownership ideals can be attributed to the students' attitude towards problem resolution. In general, students who look to the sponsor to resolve obstacles are less likely to exhibit the principle of ownership with respect to their project. In practice, students are often not able to fully explore the limits of their mistakes, as the project sponsor will hold them to a course based on a desired product outcome. This work examines the influence of ownership as a modeled quality through peer-to-peer capstone sponsorship.

Our capstone program has considered a peer-based sponsorship model to compliment the traditional academic or industry models. In this model, post-capstone students serve as project sponsors under the supervision of the instructor. This mentorship arrangement realizes the positive benefits observed using similar peer-led team learning approaches [12]. The format yields an evolving set of volunteer students rising from the capstone experience to sponsor and mentor the subsequent cohorts. There has been overwhelming positive student response to this arrangement as students are motivated to achieve based on the characteristics modeled by their peers. The expectations established through peer mentorship often transform observers into owners.

We previously introduced an undergraduate workshop into our program to promote early engagement of the capstone program with sophomores and juniors [13]. A component of the active-learning based workshop leverages the student peer model as post-capstone and current term capstone students lead the problem-based learning exercises. The effect of this "early view" of the capstone as delivered to underclassmen from their capstone-experienced peers has improved the overall quality the program and fostered a culture of achievement. In part, reflections of student experiences from this workshop led to the formation of the student-to-student peer mentorship model presented herein.

II. APPROACH

A. Concept

We have recently developed a subset of our capstone projects using a peer-based sponsorship system within our Mechanical Engineering and Materials Science program. In place of roles traditionally held by an academic or industry professional, a group of student peers who have recently completed the capstone course assume the role of project sponsor for the next phase of the their projects. Many of our capstone projects are designed to span multiple terms. The single semester format of our capstone offers this potential as students may elect to take the course in the summer, fall or

spring terms of their senior year and are therefore still enrolled in the undergraduate program post-capstone. In addition, students who have recently graduated from the program often volunteer to serve as mentors as well. With minimal capstone instructor supervision, these student peer sponsors act as the project lead for day-to-day team direction and guidance. Apart from issues related safety and budget, the student sponsors have complete control in defining project requirements, specifications and deliverables. For all intent and purpose, they set the expectations and manage all decision making for the project team. The instructor will periodically assess the adopted direction of the peer sponsors. In our program we refer to this process as "generational mentoring" – a sponsorship and leadership framework based on the previous generation of the project.

Student peer sponsors are accepted on a volunteer basis and must meet the following requirements:

- A student sponsor is only eligible to mentor a team that is a continuation of his/her team. Many of our projects are designed to span multiple years.
- Candidate sponsors must commit to the entire semester and agree to meet with their team at least once per week in person.
- All sponsors must attend a mentor training session the first week of the term.

Students are typically eager to act as a project mentor and many elect to mentor post graduation before entering the workforce or while starting their career. Past peers have commented on the value of this experience during their career search as it provides an added dimension of leadership to their training. All student peer sponsors are required to provide a written assessment of the project team at the end of the term. Student sponsors may periodically meet with the capstone instructor to gauge their effectiveness as a project sponsor.

B. Student Peer-Led Project Teams

The peer mentorship system is based on an overlapping of students between subsequent semesters. Beyond the term when the project is initiated by a founding team, each cohort establishes a new set of requirements and specifications for the incoming team. One, or several, of the students of the outgoing team volunteer to mentor the follow-on cohort in the subsequent semester. Our program offers the capstone course in the summer and therefore provides a mechanism of continuity for this process. As illustrated in Fig. 1, post-capstone students serve as a project sponsor for the continuation of the project they recently completed. Prior to engaging with their mentorship responsibilities, candidate mentors are required to attend a training workshop conducted by the capstone instructor and are provided with guidelines in support of their leadership role.

As the project transitions between terms, new peer mentors emerge from the previous cohort. These students possess the experience of mentorship from peer students as well as first hand technical experience with the project. In this context, the mentors are well positioned to define project vision, scope,

budget and timeline. A student referred to the hand-off of project leadership as generational mentoring and recognized it as a key element for project momentum; a characteristic that the many students associate with successful capstone projects. To date, our program has enrolled projects that have matured seven cohorts in this manner.

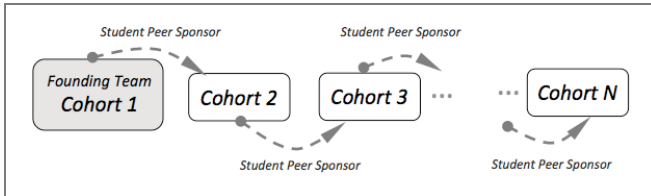


Fig. 1. Organization of Student Peer Capstone Mentorship.

C. Role of Student Sponsors

The student mentors establish all expectations for milestones and deliverables. The student peer sponsors are given complete responsibility of the team; a process that naturally defines working environment and culture whereby students are encouraged to own the process of discovery, concept development, validation and final product deliverables. A key component of the peer-based mentorship hinges on the attitude and resolution of failed approaches. The post-capstone mentors are well positioned to guide students through this process as they can draw upon their own recent experiences in a relevant context.

Student sponsors are required to meet with their team at least once per week in a defined meeting space. Our program recently remodeled and set aside a dedicated classroom for this purpose. The room contains a conference area integrated with a maker space environment. During these meetings the peer sponsors assume the role of a project leader similar to the role of supervisor a student may interact with during an internship experience. Typically, the capstone team delivers a prepared presentation summarizing project status, timeline and current challenges. The sponsors offer guidance for the upcoming week, provide suggestions for potential design approaches and triage technical obstacles. Often the experience-base of the sponsor, developed during their own capstone work, is sufficient to address these challenges. If not, the student sponsor connects them with supporting faculty or the capstone instructor.

In practice, sponsors meet with their team more than once a week and are well integrated with day-to-day activities. The background and experience of the sponsor often defines the form and extent of their mentorship beyond that of project leadership. For example, several recent sponsors have worked in a work-study capacity in our in-house machine shop. They are eager to support and train their teams with respect to manufacturing issues related to material selection, design for fabrication, design tolerances and prototype development. Past projects have required interdisciplinary engineering skills that peer sponsors have helped their teams develop. To illustrate, the sponsors of the example project highlighted below helped their team develop skills related to sensor technology and programming outside of limits of our curriculum. The

sponsors have taken the initiative to attend training during their own capstone work and were motivated to pass along the knowledge.

The capstone instructor addresses any programmatic issues such as budget constraints, unresponsive team members and workspace. The student sponsors periodically update the capstone instructor and discuss the trajectory of the project. Project team members have the opportunity to discuss challenges during the lecture component of the course.

D. Defining Appropriate Projects

Candidate projects for student peer sponsorship should be carefully considered. The project should be based on a set of requirements and specifications that accommodate broad design space. If defined properly, each cohort can choose to either build upon the work product of the previous term or move in a new direction.

Our program has considered the following projects for student peer mentorship: automated laundry folding (robotic-based), hand-held force meter for martial art, concrete canoe, practice vehicle for the FSAE team and a robotic white board sketcher. The best projects are those that leverage student interest and can be accomplished in a single term. We have realized success when coupling a project with a school-wide student club (FSAE, Aero, etc.). The first term is critical, as it should build the momentum for the subsequent terms.

E. Example Project – “Foldie”

Our programs’ first experience with peer-based sponsorship was associated with a capstone project aimed at automating the laundry-folding project. The founding team (referred to as 1st cohort) defined a set of requirements and specifications: type of garment, realistic folding rate, exit method and metrics for success. The resulting robot was given the name “Foldie” by the team as have become the characterizing label for the project and program ever since.

The first term established a form factor for the robot that has remained relatively unchanged as each cohort transitions onto the project. The knowledge base, and enthusiasm, of the founding team has been imparted to each group through the continuity of mentorship. As this group became the first of the student peer mentors, their experience was used to create the workshop for new peer mentors in the program. In cohorts that followed their capstone, they remained connected to the program and continued to offer recommendations to refine elements of peer structure. Their ideas help form the concept of student peer mentorship and are acknowledged in this work. Each of the founding members of the “Foldie” team, now established in their professional careers, offers reflections of their capstone experience and its impact on their emerging careers in Section IV.

Now in its seventh generation, the working robot is a synthesis of work products of each contributing cohort. Illustrations of the founding, 3rd and 7th generations of the robot are shown in Fig. 2. The evolution has been completely directed by the students and their peer sponsors whereby the only academic (instructor imposed) constraint has been

associated with the budget ceiling. The project, the student led concept, and the physical robot has become a showpiece of our program and is a popular choice among the incoming capstone students.

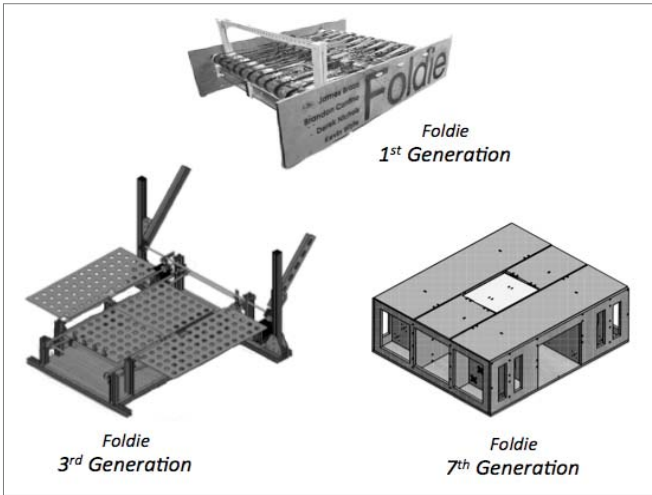


Fig. 2. Examples of “Foldie” Robot, 3rd and 6th Generations

III. IMPACT ON COURSE

The addition of student peer mentorship teams has had a distinct impact on the course. Students view the peer-based option as an added dimension to the mix of available projects. The realized benefits and advantages have been multi-dimensional impacting project quality, early engagement of underclassmen, breadth of offered projects and departmental culture.

A. Culture

The impact of peer-based mentorship on our departmental capstone culture has been transformative. The peer-led teams have emerged to be the shaping factor of the capstone program. Students in the sophomore and junior year often receive their first exposure to the capstone experience through the demonstrations of post-capstone mentors. These mentors often add value to the course lectures. During a progress presentation in one class, a student quoted his peer mentor in an effort to motivate a group that was falling behind by saying “these projects are not accomplished in leaps and bounds, but in hundreds of small steps.” Quotes of this nature seem to penetrate the culture of the course.

B. Generation of New Course Topics

Continued involvement of post-capstone seniors with the program creates an opportunity for enhanced engagement with underclassman. These seniors, acting as peer sponsors, become a catalyst for new projects as underclassman exposed to the experience have additional time to consider a topic of their own, or perhaps engage with a internship sponsor to develop a project idea for future cohorts. The peer-based model is also a natural fit for integrating student clubs into the

capstone project queue as the students in the club can act as peer mentors.

C. Student Success

To date, nearly all student peer sponsored projects have been among the highest performing within their cohorts. Within our school of engineering, capstone projects for each department compete with each other in a school-wide design expo. As the peer-led groups generally exhibit a high degree of ownership, they tend to have positive design expo experiences and the generational nature of the project leadership allow the project to mature at a faster pace.

D. Early Engagement

Continued involvement with the program for post-capstone seniors creates an opportunity for enhanced engagement with underclassman. These seniors, acting a peer sponsors, become a natural focal point for students of sophomore and junior standing as they are often seen as subject matter experts. Our program offers a capstone preparation course whereby the capstone peer mentors volunteer to deliver short presentations illustrating strong capstone skills. Their involvement has been a catalyst for recruitment of new peer sponsors.

E. Breadth of Project Offerings

Within our program, peer-based projects offer an option beyond that of academic or industry sponsorship. Students entering our capstone program provide the instructor with preferences for team selection. Often students will consider the type of sponsorship along with the projects’ technical focus. Therefore, a student transitioning to graduate school may choose a project with an academic sponsor and conversely a student interested pursuing a career with a large corporation may choose an industry-based team. However, students interested in an entrepreneurial-based experience tend to select projects with a student peer sponsor. They often cite the nature of the mentorship (and similar professional skills) as a driver for their decision as they anticipate the working environment within the team to more closely mimic that of a start-up or small company.

IV. REFLECTIONS FROM THE FOUNDING STUDENTS

Upon completion of the course, students report that working under the direction of their student peers was a defining element of their experience and driver for their success. The founding members of the Foldie team (our originating peer-based team) present comments relating their capstone experience to their careers below. Each team member is currently working in the early stages of their professional careers.

A. Comments of Founding Team Member, James Braza

“Foldie holds a soft spot in my heart. Throughout the entire project, I remember my teammates and I “willing” Foldie into existence. We worked diligently and held high

expectations. We treated Foldie like an entrepreneurial venture, attempting to create a product that didn't exist. We made a lot of mistakes along the way, but through perseverance, positive attitudes and teamwork Foldie finally came together. The following summer, I began my career as a test automation engineer at SpaceX in Southern California. During the interview process, I shared a video of Foldie robot, and I still remember my interviewer saying, "I love Foldie!" In my role at SpaceX, I worked on an automation team facing real deadlines and daunting tasks. SpaceX expected total ownership with minimal supervision, and thanks to Foldie, these concepts were familiar to me. I recently began working at a biotechnology startup, on a small team of four creating a new product line. While interviewing, I described my experience working on Foldie once again. Now I apply the same creative mindset towards rapid prototyping the product. I can attest to one realization: working in industry is really no different than working on Foldie with my teammates."

B. Comments of Founding Team Member, Brandon Contino

"Foldie was a fantastic experience of leveraging the talents of a multidisciplinary team to take a complex problem, and design and build an innovative solution. I loved solving a meaningful problem that I was passionate about with a fun and talented team. It felt as if we were a small four person start up building the next big product to be released at CES. Of all my undergraduate experiences, Foldie is one of my favorites.

After graduating I went on to co-found Four Growers, a company focused on revolutionizing the agricultural industry by providing a harvesting robot for tomato glasshouses. Since founding, I've constantly been applying the same lessons I learned in Foldie of properly identifying the problem first, testing the next unproven hypothesis, and failing fast. By exercising these lessons we've now been lucky enough to go through Y-Combinator, raise a seed round, receive funding from the US government, and secure paying contracts with farms in need.

For us, Foldie was not just a hard technical problem to solve, but also a full experience of product development from start to finish. As a team we were constantly keeping the consumer in mind and any engineering decision we made was constantly evaluated against the value it would bring the consumer. For me, Foldie taught an incredibly valuable lesson of how to focus on the most critical metrics in a solution, what the consumer needs."

C. Comments of Founding Team Member, Derek Nichols

"Foldie was by far my most memorable experience throughout undergrad. It was the first time that I had a class where I worked on something more practical than coursework. In addition to learning skills in design such as design feasibility, fabrication, and implementation, I learned countless soft skills along the way like communicating effectively during presentations, giving and receiving criticism, learning how to fail and how to

iterate on those failures to improve the design. The development of these skills was made possible by taking this course and was accelerated because of the fact that the project was our own.

Directly after undergrad I enrolled in graduate school to pursue a PhD in mechanical engineering working on a project with The Boeing Company. Not a day goes by where I don't use a skill that I learned from working on Foldie. By far the most important for research to me is learning the benefits of failure. Every day I fail in one way or another - my experiment doesn't work, I didn't get the data that I was expecting, my setup doesn't fit together, etc. Before Foldie, I expected that everything would always work the first time around, but I quickly learned how wrong I was in that assumption. I learned how to accept failure and how to use it as a learning experience.

Another important skill that I learned was how to effectively communicate ideas in ways that everyone will understand. Something that seemed so simple to us as a team had to be explained in ways that allowed groups of people with no knowledge to easily follow along. This became important when explaining our project to the public and then again when mentoring the next group to take on Foldie. This skill is paramount in academia. When presenting work at conferences or teaching a lecture to a class, it has to be broken down to fundamentals so that no listeners are lost along the way. Without the skills that I acquired while working on Foldie, I wouldn't be the researcher or person that I am today."

D. Comments of Founding Team Member, Kevin White

"There were a few aspects of the project that really stood out to me. As a team, we showed more dedication and drive than I've experienced in a classroom setting before. Additionally, since this project was very software and electrical engineering heavy, the team had to show competency in areas outside of their major. Through every set back, it was the energy and drive of our team that made the project continue onwards.

Having worked now for a few years, it's easy to see many ways in which this project prepared me for my first job. In short this experience showed me self-motivation. At any job you have, you are given problems to solve. Something that has and will always make an employee stand out is when they find and solve a problem that they aren't asked to solve. This project gave me first hand experience to look out, identify a problem, and work towards coming up with a solution without a professor or manager assigning it to me.

Foldie was the first project in college that asked me to focus on "the why". I refer to "the why" as the reason behind your work. With Foldie, our team was allowed to create "the why". Our team wasn't worried about checking off requirements for a class, but rather creating something that we were proud of, and that made us all more devoted to the project. "The why" for me at work gives me dedication to perform my work duties to the best

of my abilities and always look for opportunities to improve.”

V. STUDENT COMMENTS

Upon completion of the capstone course, students often provide feedback and comments to the capstone instructor regarding their experience working within a peer-sponsored team. Highlights are summarized below.

- *“The key to a successful senior project is momentum, and generational mentoring allows more of that momentum to be sustained from semester to semester.”*
- *“We really enjoyed working with our student mentors and would definitely recommend that this idea [peer mentorship] be continued in future iterations of the course. The primary reason was availability and first hand experience”*
- *“I am more comfortably taking risks with my fellow classmates as project sponsor. There is less anxiety associated with mistakes along the way.”*
- *“Our peer sponsor truly cared about the success of this project; their dedication to a working final product definitely motivated the team. They pushed us at every turn to find a solution to every problem. Their enthusiasm and passion were infectious.”*
- *“I strongly believe that this type of experience should be a mandatory and frequent part of engineering education.”*
- *“One advantage of peer mentorship is a challenging project can seem more attainable. An open-ended project may seem impossible and/or overwhelming if presented by a faculty member or industry professional. However, if presented by a peer, suddenly the student may realize that all it takes is stepping up to the plate.”*

VI. INSTRUCTOR COMMENTS AND DISCUSSION

Students’ working with post-capstone mentors report that working under the direction of their peers was a defining element of their experience and driver for successful outcome. The student-to-student mentorship fosters a principle of ownership among the team. Independence and self-reliance appear to be inherent by-products of the peer relationship. This relationship will continue to be a subject area of research for our program.

As noted in one of the student comments, momentum is a key element of a successful senior project. On the surface, the peer-based teams are better positioned to retain momentum as compared to academic and industry sponsorship. Along with the transfer of technical knowledge, these teams more directly channel project culture and vision; potential measures of momentum.

Peer-based teams commonly report that their peer mentors are more approachable and available than faculty or industry professionals. This may be an artifact of the student viewpoint as faculty and industry sponsors typically volunteer to serve in these roles and exhibit strong commitment. It may be that students feel more comfortable contacting their student peers with greater frequency or with respect to minor issues. Future cohorts will be surveyed to develop a better understanding of student expectations with respect to mentor availability.

Properly implemented, the use of peer-mentorship can be a driver for a capstone program. The peer-to-peer “story” and resulting project products have become a showpiece for a program fostering early engagement of underclassmen and recruitment of potential students. In a sense, the capstone is a competitive environment and there is a need to establish clear positive examples.

Success in the capstone project is among the defining metrics characterizing an undergraduate education. Combined with traditional sponsorship models (academic and industry-based), a peer-to-peer form of mentorship offers an optional opportunity for success for students seeking experiences of an entrepreneurial nature. Examination of this format offers a new lens on the principle of student ownership within the capstone project thereby adding to the discussion of product and process-driven experiences.

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