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Board 8: WIP: Proposing a Novel Nested-Team Approach for a Biomedical Engineering Capstone Design Project

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Work in Progress: Proposing a Novel Nested-Team Approach for a Biomedical Engineering Capstone Design Project

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Abstract

The traditional idea of capstone teams is assigning a project to a group of students which will be tackled throughout an academic term. The team can comprise students from a single major or multi-disciplinary (e.g., multiple majors). The project can span one or two semesters; in some exceptions, new teams are tasked with further project phases for the following years [1]. This work aims to present a novel approach to structuring capstone teams. By deconstructing a single project into multi-deliverable components (e.g., heart rate sensor divided into software, hardware, and housing) it allows each team to tackle detailed and specific objectives within the span of the academic year. This restructuring requires some foresight into the project's main deliverables but does provide the opportunity to attain more fine design objectives than traditional team structures.

The nested teams were implemented on a project to create a remote-sensing application for medical monitoring. This application requires students to design a device to detect vitals to send to a provider. This project was divided into four teams: hardware, software, housing, and integration. The goal of this restructuring was to recreate a more real-world scenario in which each team in a cohort can work off each other and communicate to achieve their desired outcome. These four teams met twice a week and were required to coordinate communication with both the client and each other to stay on task.

Two main challenges were observed during implementation: communications and ownership. The teams were required to build and sustain clear lines of communication to ensure that specifications were understood by all stakeholders (e.g., communicating the limitations of the sensor). Teams were also required to discuss ownership of design decisions and come to agreements on implementation (e.g., which team decides the implementation of a cooling solution).

Introduction

The traditional idea of a capstone team is assigning an engineering-related project to a group of students which will be tackled throughout an academic term. The project can span one or two semesters; in some exceptions, new teams can be tasked with additional phases of the same project for multiple years [1]. The teams can consist of students from a single major or multiple majors [2]. The projects can range from various topics and often depend on a department or faculty's experience and expertise. Capstone courses can also benefit from industry sponsors that fund the projects and often expect a deliverable at the culmination of the term. This unique opportunity can present students with new learning opportunities and challenges that can enhance learning outcomes [3]–[5]. Working with sponsors does come with challenges. Sponsored projects can sometimes overwhelm students or be incorrectly scoped for the time available. Additionally, some of these projects' scopes intersect with other fields of expertise and require students to learn content beyond their training. Another challenge with sponsored projects is balancing the student's learning outcomes with the expectation of a deliverable. Often, sponsors conclude their collaborations if they perceive that little or no progress has been made on their project. With or without sponsors, the idea of capstone courses is still shared across all programs; capstone represents the culmination of students' academic learning..

This work presents a novel approach to restructuring capstone teams to address the challenges of working on sponsored projects. The goal is to deconstruct a single project into focus areas and assign a group to one of these areas rather than one group overseeing the entire project. In the example of a heart rate monitoring device, multiple teams would tackle the device from the perspective of hardware, software, housing, or any additional functional area. The idea of dividing work along functional tasks or skill focuses is not new [6]–[8]. Previous literature has examined how engineering teams often divide their work along each student's perceived skill sets or strengths [6]. This division has often been left to students to decide or has been suggested by faculty. Formalizing this division as part of the team formation in the context of a capstone course is unique. This restructuring would also allow students to work in an industry-like environment where teams have specific tasks and communication is critical. The particular use case presented in this paper is to create a remote-sensing application for vital sign monitoring. Some details will not be included to avoid IP infringement with the sponsor of this project.

The assessment plan is to evaluate if this new team structure improves learning outcomes compared to a traditional team. The two outcomes being compared in this study are ABET student outcome 3 and 5 by measuring student's communication and self-efficacy relative to other team structures (e.g. other capstone section). ABET 3 (Communication) relates to the *ability to communicate effectively with a range of audiences, while* ABET 5 (Teamwork): relates to the *ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet* *objectives.* This is the first instance of this restructuring being performed at The Ohio State University (OSU) biomedical engineering capstone course.

Previous Experience and Challenges:

The capstone instructor attempted a similar project in the past year (2021-2022). The course ran for two semesters and had a total of 14 students divided into four teams. The teams were formed after students from a pool of 80 rank-select projects they were interested in. The project was developing a device to monitor vitals remotely. Each teams was defined by specific use cases, which included monitoring patients of different ages or in particular locations in a home. Each team was tasked with a specific modality, but all groups had to design a minimally viable prototype for remotely sensing vitals. The challenge with this project was using a new technology that required students to learn not only the fundamentals of this technology but be able to use it effectively. On top of that, students needed to design the software required to process the sensor information, the hardware to ensure that the sensor worked, and a housing element to encase everything. All of these while considering a specific use case. At the end of the academic term, all four teams focused on one aspect of the challenging project. One group had progressed significantly on the software/algorithm to evaluate the sensor data, another had designed a great housing, another had worked on the computing module, and the last had automated data collection. No group was able to provide a clear and complete prototype. The lack of a finished product from a single team motivated the restructuring presented here.

Course and New Team Organization:

The team restructuring took place in the academic year of 2022 to 2023 with a new capstone course sequence (two semesters). There was a total of 11 students and three teams. The first team had three students and was focused on the hardware. Hardware was responsible for the sensor modules, the external computing module (e.g., raspberry pi), connections for the sensors, power supply, and memory storage, among other hardware considerations. The second team had four students and was focused on the software. Software's scope included creating code to connect to the sensors and designing an algorithm to automatically detect vitals (e.g., respiration and heart rate). The third team had four students and was focused on housing and integration. Housing's responsibility was to create an encasing for the device, evaluating the correct materials and dimensions. At the same time, integration investigated the patient's homes to ensure the device would fit the user's needs and constraints.

For this course iteration, assignments and academic expectations for the teams remained the same as in previous years. In the first semester, teams would meet with the faculty once a week and then at least once more without the faculty. In the second semester, teams would only meet every other week with the faculty and utilize the additional time to work on their projects. The first semester the course went through the design process by having students focus on market analysis, ideation, concept sketches, and project management. The students submitted a report proposing their design at the midpoint of the first semester. In the second half of the first semester, the students began working on prototyping a minimally viable solution for their design scope. In the second semester, teams revised the design and implemented feedback from the previous semester's presentation. Then the second semester focused on building and validating the device through multiple iterations. All the work concluded with a presentation to the sponsor and faculty, where students showed their completed prototype.

Planned Assessment and Observations:

The goal for this study is to compare how the new team structure impacts student learning outcomes compared to a more traditional team structure. Specifically focusing on ABET outcomes 3 (Communication) and 5 (Teamwork). To assess communication surveys will be implemented between team members and between team members and sponsors. The surveys will measure communication frequency, clarity, and openness. Additional questions will include how teams handle conflict and how they view progress. To assess teamwork effectiveness a self-efficacy instrument will be implemented. Self-efficacy is defined as *"an individual's belief in his or her capacity to execute behaviors necessary to produce specific performance attainments"* [9], [10]. Both of these assesments will be implemented in mid-semester evaluations and at the end of each semester; four total assessment points.

Anecdotal observations for this restructuring include increased teams' sense of initiative and agency in problem-solving. Groups were encouraged to meet and communicate openly amongst themselves. In the second semester, a significant increase in interactions was observed. The hardware and software teams met in the classroom to improve data acquisition since the hardware team collected sample data. The housing team kept in touch with the hardware team to ensure all components were considered for the device's encasing. Most interesting of all was the integration team. This team took the initiative to talk to all groups and communicate the constraints observed in all patient's homes. During the first semester, communication was a concern, but this cohort of students surpassed all expectations.

Some of the challenges with this restructuring included having the foresight to scope the project accordingly and ensure all students hit the course's learning objectives. Luckily for this first attempt, it was possible to scope the project in high-level focus areas (e.g., software, hardware, etc.), given the same project ran the previous year (2021-2022). Learning outcomes would require finding ways to evaluate students' mastery of skills and comparing them between capstone groups. This evaluation would be possible given that OSU's biomedical engineering department holds multiple capstone sections with different faculty.

With all considerations, this new nested-team restructuring holds promising prospects for running a practical, more real-world experience for students. This approach has a low impact on the teaching load. It addresses some of the challenges with sponsored projects: team effectiveness, progress, and communication. Lastly, it helps the students feel supported by having a aid from peers to tackle challenging concepts.

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