A Vertically Integrated Design Program Using Peer Education

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Work in Progress: A Vertically Integrated Design Program Using Peer Education

Introduction

A yearlong capstone project for fourth year undergraduate biomedical engineering students is often put forward as the model for engaged, experiential learning [2, 3]. However, preparing students to undertake the breadth of such a project is often overlooked. In most undergraduate engineering curricula, there are typically limited opportunities for second or third year students to practice the design skills employed in a capstone project. These skills include engaging in project-based learning with a scope beyond a one semester course, developing physical prototypes using an iterative process, or performing verification and validation testing on a self-designed prototype.

One approach to exposing students to these skills in the context of a design project is by utilizing vertical integration. Vertical integration is a pedagogical practice in which didactic learning takes place alongside experiential learning. In practice, foundational skills are taught along with applied skills. Within the context of biomedical and medical education, basic sciences are taught alongside clinical sciences [4]. This approach has been shown to improve both student knowledge and clinical skills [5, 6]. In an undergraduate engineering curriculum vertical integration has previously been used to improve student engagement through concurrent teaching and utilization of the concepts. More specifically, in an engineering design course a combination of professional, ethical, technical, or communication skills are both taught and used [7, 8].

Vertical integration can give students exposure to design skills prior to a fourth year capstone project; yet, it does not inherently provide a context for the experience. Industry, service learning, or academic research could all fill this criterion. Industry or service-based vertical integration is perceived by students to be ‘real-world’ experience and has been shown to increase participation and learning outcomes [9, 10]. Research-based vertical integration could be similarly valuable. Participation in faculty research has the benefit of giving students exposure to graduate school, ensuring project continuity, providing technical expertise, and accelerating faculty research output [11, 12]. The drawbacks to utilizing either of these approaches are twofold. First, students do not participate in the problem identification process, as this is typically done by a non-student stakeholder. Second, students have limited access to the stakeholders who are not necessarily able to participate in problem identification or project implementation. Peer education, in the form of capstone students themselves, is an alternative source of vertical integration experience. Such a vertically integrated peer education model has previously been demonstrated for the purpose of creating course content [13].

In this work in progress study, vertical integration combined with peer education will be applied to a series of biomedical engineering design courses made up of second, third, and fourth year students. The implementation constitutes both second and third year students participating in a fourth year capstone immersion experience designed to emphasize design and prototyping skills taught in their respective biomedical engineering design courses. The results will be evaluated with respect to second and third year students’ attitudes and ability to demonstrate biomedical engineering design skills. The value added to this approach is for second and third year students to gain experience with the design process and early exposure to prototyping skills. Secondary benefits may also be extended to the capstone students in the ability to practice professional skills which are generally considered lacking in many project based learning courses [1]. This includes leadership, communication, and project (both human and task) management.

Project Approach

Vertical integration with peer education is a curriculum-wide effort in the design courses for second, third, and fourth year students. The study takes place via a three week immersion experience in which both second and third year students are transiently and sequentially embedded in a fourth year capstone project. All students participating in this project receive class credit.

As a precursor to the capstone immersion, both second and third year students receive both large-group and laboratory training to prepare them for the design immersion. Second year students receive large-group topics on existing clinical solutions, concept generation, concept benchmarking, and document control. Simultaneously, they participate in technical skills modules that include topics for computer-aided drafting (SolidWorks), embedded systems (Arduino), 3D printing, laser cutting, mammalian cell culture, and bacterial cell culture. Third year large-group topics include needs validation, design control, test strategies, and technical writing. Planned third-year technical modules include: printed circuit board manufacturing, machining, polymerase-chain reaction (PCR), and gene editing.

The second and third year students are integrated with the fourth year capstone team in a 2-hour lab section to apply their newly acquired skills. There are two nodes of capstone experience integration. The first to take place chronologically is the interaction between second and fourth year students. The node is initiated by the fourth-year capstone students who, after validating an unmet medical need, present their design concept to second year students. Second year students in groups of 4-6 are then paired with capstone teams on the basis of self-identified interest in the project deliverables. Second year students (under the leadership of the capstone students) begin the prototype development. After three weeks, the prototype and documents are given to the capstone students who initiate a design review and begin a new design iteration.

The second interaction is between third and fourth year students. It consists of a three week capstone immersion which takes place over a 2-hour lab section as part of the biomedical engineering design course. The focus of this interaction is verification and validation of needs, designs, and prototypes. Before the immersion, capstone students complete their prototype development and define the testing strategy. The testing strategy is approved by the instructor and presented to the third year students. After approval, teams of 4-6 third year students participate in device testing along with capstone students. Third year students will share in executing good engineering practice while taking part in risk assessment, experimental design, prototype testing, systems integration, or data analysis. Following the peer immersion, capstone students analyze the data and validate the outcomes to the design inputs. A graphic summarizing the project is described in Figure 1.

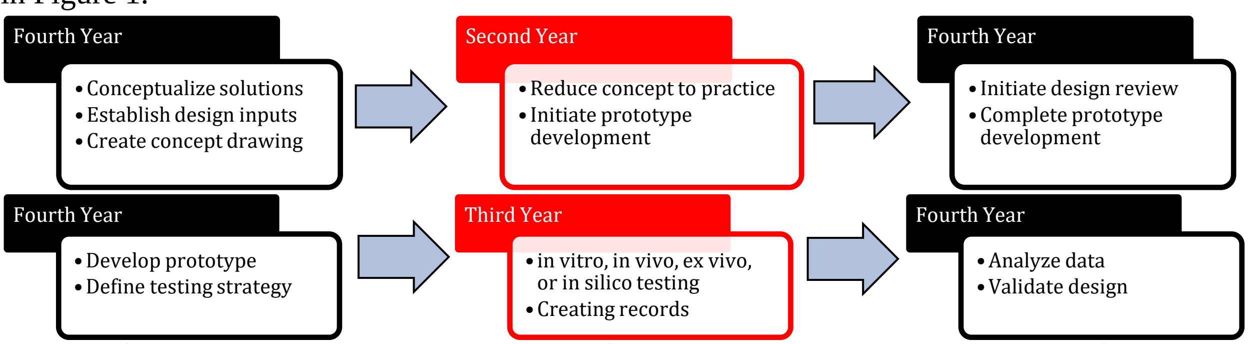

Figure 1. The flowchart depicts the overlap between second, third and fourth year students. Second year students are immersed after a concept has been articulated and prototyping can begin. Third year students are immersed after prototyping to participate in verification.

Both the student and project outcomes will be assessed. Second year students' attitudes and prototyping skills will be assessed using a self and project evaluation survey both pre- and post-immersion experience. The topics of the survey include: motivation to continue the design project, confidence in using prototyping tools, and an understanding of strategies common in biomedical engineering design. They will also have a pre-immersion and post-immersion technical skills assessment. The skills assessment is a laboratory practical in which students are asked to independently demonstrate the learned skills. An instructor-observer verifies the number of properly performed tasks. For example, in the cell culture module the instructor-observer checks that aseptic technique has been used, the proper pipette has been selected, the samples are visible under the microscope, and the correct conclusion about cell health has been made by the student. Third year students will be assessed using a similar instrument. The topics of the self and project evaluation survey would include: testing strategies, testing equipment, and ability to independently synthesize experiments. A pre-immersion and post-immersion technical skills assessment will also be given. Fourth year students will be evaluated with a survey which assesses project management skills and student leadership. Their projects will also be evaluated with respect to the number of completed projects and time to completion.

Results and Discussion Outlook

The novel aspect of this study is that vertical integration, comprised of only undergraduates working on projects identified by undergraduates, is being used to teach and reinforce prototyping skills. Fourth year students are peer educators in instructing these skills while simultaneously working on projects they have identified. As a curriculum, the approach gives students early exposure to needs assessment, needs validation, and prototyping skills in the context of a capstone project. Future capstone students are thereby empowered to select needs earlier and focus on the technical aspects of their project. This is accomplished by having second year students create technical drawings, develop embedded systems, culture human or bacterial cells, and participate in prototype fabrication of either complete designs or subsystems all within a capstone project. These students will gain mastery through repetition, practice translation between abstract representations and physical products, implement quality management systems, and observe the bio-design process. Third year students will primarily be tasked with verification and validation of designs and unmet needs. Outcomes from fourth year students are principally management and leadership training. They will have the opportunity to serve in the capacity of a project manager whose responsibility is to establish and communicate training, deliverables, and schedules. As peer educators, fourth year students are responsible for providing context to the technical skills and instructing underclass team members in the implementation of deliverables for the project.

A potential criticism of this approach is that by immersing second and third year students work is being taken away from capstone students. Yet, it should be noted that past capstone projects (without immersion) have rarely progressed to completion. Those which are completed have had poor quality prototypes. Assistance in the form of additional man-hours can address a portion of this problem. Nevertheless, to ensure that too much work is not being done by immersion students, the scope of the second and third year student's work is approved by the instructor. The immersion is also limited to three weeks. Three weeks is not likely adequate for complete prototype construction or validation, leaving substantial work for fourth year students. Rather, additional student work could allow capstone students to expedite design reviews, iterate prototypes, and complete all deliverables.

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