Work in Progress: Biomedical Prototype Design in Collaborative Teams to Increase Students' Comprehension and Engagement

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Kiersten Lenz is a graduate student at the University of New Mexico in Biomedical Engineering. She has previous experience as a secondary science teacher at the high school level. Based on her observations as both a teacher and a student, Kiersten believes that the most effective way to teach is through creative lesson plans paired with collaborative problem-based learning.

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Eva Chi is an Associate Professor in the Department of Chemical and Biological Engineering Department at the University of New Mexico. The research in her lab is focused on understanding the dynamics and structures of macromolecular assemblies including proteins, polymers, and lipid membranes. Undergraduates, graduate students, and postdoctoral scholars are trained in a multidisciplinary environment, utilizing modern methodologies to address important problems at the interface between chemistry, physics, engineering, and biology preparing the trainees for careers in academe, national laboratories, and industry. In addition to research, she devotes significant time developing and implementing effective pedagogical approaches in her teaching of undergraduate courses to train engineers who are critical thinkers, problem solvers, and able to understand the societal contexts in which they are working to addressing the grand challenges of the 21st century.

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Dr. Vanessa Svihla is a learning scientist and assistant professor at the University of New Mexico in the Organization, Information & Learning Sciences program, and in the Chemical & Biological Engineering Department. She served as Co-PI on an NSF RET Grant and a USDA NIFA grant, and is currently co-PI on three NSF-funded projects in engineering and computer science education, including a Revolutionizing Engineering Departments project. She was selected as a National Academy of Education / Spencer Postdoctoral Fellow. Dr. Svihla studies learning in authentic, real world conditions; this includes a two-strand research program focused on (1) authentic assessment, often aided by interactive technology, and (2) design learning, in which she studies engineers designing devices, scientists designing investigations, teachers designing learning experiences and students designing to learn.

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Introduction

The goal of engineering programs is to graduate students who have technical, interpersonal, and conceptual competence. When our department was awarded funding to achieve that goal, we incorporated a semester-long prototype design project into our biomedical engineering course. Integration of hands-on activities into course curricula increases students' investment in learning, understanding of concepts, and gives them an opportunity to develop technical skills [1]. Design challenges that are related to real-world issues can help students understand course relevance and their role in solving those issues [2]. Collaborative, active learning tends to improve comprehension when compared to traditional lecture methods [3]. Based on these educational principles, we restructured a primarily lecture-based biomedical engineering course to include team building activities, hands-on design challenges, and a prototype design project.

Literature Review

During their engineering education, students must prepare for a workplace that requires them to collaboratively problem-solve and design. Incorporating design challenges across the engineering curricula, although difficult at first for instructors, has immense benefits on student learning outcomes [3]. Students who are supported in design projects that include hands-on learning report more positive feelings about the course when compared to a traditional lecture-style class [4]. Additionally, students appreciate the opportunity to practice essential engineering skills (e.g., computer aided design, manufacturing, and prototype testing) [4].

Working in collaborative teams increases critical thinking, test scores, and student engagement with the material. Additional positive outcomes are increased self-esteem, personal asset identification, and a gained appreciation of diverse perspectives [5]. Providing students with the opportunity to reflect on key areas of teamwork, such as communication, task management, and cooperation, can increase the effectiveness of team work [6].

Research Design and Methods

This study evaluates the effect of a collaborative prototype design project on students' learning outcomes and engagement with course material at a large Hispanic-serving research university in the Southwest. The students were enrolled in a biomedical engineering course that included undergraduate, graduate, and shared credit BS/MS students (N= 11). The course focus was on the development of technologies to address global health issues. Graduate students worked in assigned teams of three or four to design a device that could help an underdeveloped part of the world. Teams chose the specific country and health issue of interest to them. They were given a maximum budget of $25, reflecting the resources of emerging global economies, as well as access to a local makerspace. The teams worked collaboratively throughout the course on challenges that progressed their design, including periods devoted to working on prototypes. Components of the design project were aligned with traditional lectures, quizzes, and homework that covered the same content. Simultaneously, undergraduates served as representatives of a funding agency of their choice. They created a brochure with a Request for Proposals, as well as a rubric that they used to evaluate the graduate students' projects. The undergraduates also participated as a team with the instructor on intermittent team-building course challenges.

In the final class period, the teams presented their prototypes (either in-person with accompanied slides, or video-recorded) to the instructor and the panel of undergraduates, in which they addressed the requirements of the funding agencies as well as the instructor's criteria. The scores were averaged by the instructor, and used to "fund" the winning projects. The final designs included a UV-powered light capable of killing 99% of typhoid bacteria using a hand-cranked generator, an electricity-free nebulizer, and a low-cost method for catching the intermediate hosts of the parasites that cause schistosomiasis.

Anonymized, open-ended reflection questions were given to students after each in-class activity. We qualitatively analyzed these for students' comprehension and opinions. An end-of-course survey was conducted to gauge how students and the instructor felt about the class overall.

Results

We found that the collaborative prototype design project positively influenced students' feelings about the class and their comprehension of course content. The students reported that the class structure helped them feel engaged with the material and allowed them to gain real-world skills such as task management and cooperation. They also reported feeling altruistic and motivated to make broad impacts in the field of global health. One team is patenting their prototype in order to be able to donate it to areas in need.

When asked to "Explain how the experiences you had in this class shaped your educational or career goals," students responded with enthusiasm. A few notable student responses are highlighted below:

> "The class really gave me a different perspective on the broader impacts of global health. Beyond that I appreciate the opportunity to design and brainstorm a prototype based on a healthcare need."

> "This class made me consider big picture health issues and my part in solving them as a biomedical engineer."

> "I really enjoyed this class, I feel like I have a better understanding of the world and how people and government can make a huge impact on health at all times. Before I only had minimal knowledge about infectious diseases and technology and now I think I can use this class for the rest of my career."

As importantly, the instructor reported that she found a higher degree of satisfaction in teaching the course, because frequent formative assessments gave her more opportunities to understand and address the students' individual skills and limitations. She also observed that this class of students performed better on summative assessments when compared to previous years.

When asked, "How do you think the design project affected your students' learning?" the instructor stated:

> "I believe it greatly enhanced their learning. Each team identified a health problem in an area of the world that they were most interested in, and used that as the basis for their project... I'd been concerned that they would focus on the project to the detriment of their HW and exams, but I saw the opposite—it seemed that it ignited an interest in the subject that made them work harder."

When asked, “What are your final thoughts on the design project now that it is completed?” the instructor stated:

> “I am a convert to project-based learning! I was thoroughly impressed with the creativity, level of effort, and thought put into each of the final designs. Two of the final projects were so novel and creative that they are actually patentable.”

Implications and Future Work

The integration of a semester-long prototype design challenge in collaborative teams had a positive impact on students’ comprehension and engagement with course material in our biomedical engineering class. The project gave students the opportunity to develop applicable skills, both technical and interpersonal, for the engineering workforce. Students’ views on global health were broadened, which in turn increased their motivation to help others in need. This prototype design challenge will continue to be used in future course offerings. We plan to include team-building activities earlier in the course to enable effective teamwork from the start. We also intend to work together with other faculty members in our department to incorporate design projects in more of our engineering courses.

Acknowledgments

This work was supported by the National Science Foundation (EEC # 1544233).

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