ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE
Paper ID #36829

# Work in Progress: Rethinking two separate engineering and mathematics capstone courses at a small liberal arts university

**Girish Upreti**

**Denise H Bauer (Associate Professor)**

**Jie Zhou**

Jie Zhou, an associate professor of Mathematics at Methodist University, is interested in interdisciplinary studies and math education in engineering besides his own field of research in mathematics.

# Work in Progress: Rethinking two separate engineering and mathematics capstone courses at a small liberal arts university


## Abstract

Almost all engineering programs have a capstone course requirement where students apply their content knowledge to a culminating open-ended problem-solving experience. Due to the much lower student enrollment number in small liberal arts colleges/universities than public universities, the class size of capstone courses is much smaller, which leads to potential problems in efficiency and sustainability. The Engineering Department and the Mathematics Department at Methodist University decided to collaboratively redesign the capstone courses to enhance the student research experience and efficiency of resources. The result is a joint capstone sequence consisting of two 2-credit courses for each department. Unlike the traditional two back-to-back courses in the senior year, our first course in the sequence will be in the spring of the junior year and the second is in the spring of the senior year; both will be offered at the exact same time so that joint sessions can be held for all students in the capstone courses. The idea is to create a learning environment where senior students become mentors, and junior students can learn the expectations and requirements from observing the seniors during joint sessions. The joint sessions across the two departments will also provide the opportunity for the double majors to work directly with students from both departments. The capstone course during the junior year will simulate the approach of the senior capstone course and provide engineering design and mathematic problem-solving experiences so that students are able to identify potential project topics and create client contacts earlier in the process as well as connect additional course content directly to the projects. Since the new capstone sequence was approved by both departments only recently, it will be a few years before the implementation of the sequence, which allows us to collect and analyze more qualitative data in the current capstone courses before finalizing the joint capstone sequence. In the future, qualitative data will be collected from the joint capstone sequence to compare students' experiences in the classroom as well as their career preparation.


## Introduction

A capstone course offers students an opportunity to synthesize and demonstrate their knowledge in the field of their discipline as well as hone the skills necessary in the workplace. They are an important part of engineering education and also a requirement by ABET. A study led by Gewirtz in 2017 [1] shows engineering students benefit from a capstone design course in their transitions into the professional world. Many engineering programs have a capstone course requirement so that students get exposure to open-ended problem-solving, and often a culminating engineering design project is a major part of the course. Several years ago, the Mathematics Department and the Engineering Department at Methodist University developed their own capstone courses independently, and currently, they are teaching the courses separately. For students who are double majoring in engineering and mathematics, they are required to take the capstone course in the math department to fulfill the degree requirement. The arrangement allowed engineering/mathematics double majors to only need one capstone course but did entail that the students complete a project that was both engineering and math-related.

How this was accomplished varied from student to student – they could improve the mathematical model within an engineering problem or work with a team from the engineering capstone but add a mathematical component to the project, to give a couple of examples. While the arrangement works, the two departments realized it could be improved from both the student and faculty perspectives.

Our institution is a private liberal arts university with an undergraduate student population of around eighteen hundred. Most upper-level classes in engineering are relatively small, even more so in mathematics, which causes potential issues with the sustainability of the current capstone courses. As a result, it is possible the mathematics department will not offer their capstone every year. Low numbers also mean a decrease in student interactions that drive collaboration and idea generation, which would reduce the overall student experience. Both departments decided to redesign the capstone courses in an effort to improve student research experience and efficiency on resources.

**Proposed change**

We propose a joint capstone sequence consisting of a series of two courses, which is a trending practice according to a 2015 survey [2]. After offering a single capstone course during senior years for several years, we found that there was not enough time for math students to conduct any quality research, and for engineering students to provide and test a high-quality solution to a complex design project. As opposed to two courses back-to-back in the senior year found in many engineering programs, our approach is to offer the first capstone course in the spring of their junior year and the second in the spring of their senior year. Instead of one three-credit senior capstone course, each course is redesigned to two credit-hour course series instructed by a professor from either the math or engineering department, collaborated with another faculty mentor from the other department. These two faculty will teach the capstone courses for that semester to make it more efficient. The School of Mechanical Engineering at Shanghai Jiao Tong University redesigned their capstone course offering a series of two capstone courses but with different weights [3]. They are offering one credit in the spring semester and 3 credits in the autumn semester. Some schools have redesigned their capstone course with a year-long program offering a one-quarter lecture course followed by a two-quarter industry-sponsored capstone project [4].

In the first capstone course, we will go over some topics from the mathematics courses they already took, for example, Calculus, Linear Algebra, etc. This will allow engineering students to solve a substantial problem for their future project with knowledge gained from mathematics courses. The technological method of problem-solving will be discussed in class by an engineering professor and the engineering students in that class are expected to apply the best practices in design and project management in the second capstone course. Mathematical problem-solving strategies will be discussed as well in this course. According to a study by Cardella and Atman in 2005 [5], engineering students rely on mathematical problem-solving strategies in their project design, even though they are not fully aware they are using mathematics.

All students will be asked to explore research/project ideas by surveying published papers and project reports. There are two to three 10-to-15-minute student presentations in class on different topics with their last presentation on a paper/report that relates to a topic they are interested in exploring further for the culminating design experience. Oral communication is a major component of this course. In this course, as in industry, proficiency in the communication of ideas is very important [6] since it is crucial for working with clients and other members of the team.

Prior to the second capstone course, students are expected to conduct necessary literature research for their projects. After the course, students will be tasked to find a research project on their own, or pick a team project provided by the end of the fall semester so that they will be ready to work on the project in the following semester.

Problem-solving will be reviewed again in their second capstone class. Students will start working on their projects in the course under the supervision of a professor from the corresponding department. In addition to the project design, we will spend class time on professional topics such as professional citizenship, commitment, and active listening, which will potentially help students transit as entry-level engineers [6]. Communication is going to be emphasized again and is a major part of the assessment of this course with several milestones consisting of presentations to various audiences including the client, students within the class, and a general audience during the university-wide symposium.

While the main requirements of the capstone sequence are the same as capstone courses at other universities, the difference is that students will be learning from direct interaction within the classroom. The most important feature of the new capstone sequence is that all courses (junior/senior, engineering/mathematics) will run concurrently so that joint sessions can be held. This will allow lectures on technological problem solving and professional topics with all students, which will increase the depth and breadth of discussion. Additionally, the juniors will have the opportunity to directly learn from the seniors. The lecture content for both cohorts would be the same. We believe this is the most exciting part of the new capstone experience. By combining the courses, the juniors will have the chance to attend presentations made by the seniors, sit in on client meetings, witness teamwork, and gain an idea of what is required of a senior capstone project. Although these skills can be taught through course lectures and student practice, being able to observe someone else going through the process will help the juniors directly learn presentation skills, the course requirements, and expectations. The expectation is that the juniors would then be more prepared to execute their own capstone project the following year.

It may seem that all the benefit is for the juniors, but the seniors should also gain a richer experience from the joint capstone design. These students are preparing to enter the workforce or graduate school, and learning to mentor and teach others would be excellent skills to take with them. It is highly likely that each of the students will need to interact with those that are not as knowledgeable on a subject or will be overseeing a group of individuals. Working with the juniors in this capacity will help each student gain confidence in their own knowledge as they guide others through the same process and give the juniors feedback on their own presentations and potential capstone topics.

**Assessment**

We will initially begin to collect data from past and current students on the capstone design and experience. We would specifically look to ensure we get feedback from the double majors as they were the students attending one capstone course (mathematics) while having to abide by engineering requirements. The capstone courses will be assessed by analyzing the quality of the senior project design and qualitative data collected from students right after finishing the capstone project.

When the new capstone sequence is implemented, students will be given a survey of the first capstone course at the end of the sequence. In that survey, we will ask whether certain components in the curriculum of the junior capstone course help them prepare for the senior level course. The results will be analyzed and utilized to improve the junior capstone course. In addition, we will try to follow up with our students six months after their graduation to gauge whether the capstone sequence eases their transition into business and industry, or graduate studies. In particular, we will ask specific questions on self-learning, communication, scheduling, and the impact of senior projects. Data will be collected and analyzed to first determine if the capstone change did, in fact, increase student learning. The data will also help us make necessary adjustments to strengthen the senior capstone course.

**Summary**

Overall, the first capstone course will simulate the approach to the senior capstone course and provide engineering design experience by introducing all the components of teamwork and the design process, which will prepare students for their senior project design. A semester separation between two courses will give students ample time to identify their project topic and carry out necessary background research before the second capstone course, thus they will spend time solely on the project during their last semester. Changes and tweaks will be made to each course based on the feedback from students and faculty to improve student learning outcomes outlined by ABET. More importantly, the sequence will be designed and improved to equip students with technical skills and professional skills, which will prepare students to meet expectations from the industry and ease students' transition into the professional world.

## References

[1] C. Gewirtz, D. A. Kotys-Schwartz, D. Knight, M. C. Paretti, S. Arunkumar, J. D. Ford, S. Howe, L. M. Rosenbauer, N. E. Alvarez, J. Deters, and C. Hernandez, "New engineers' first three months: A study of the transition from capstone design courses to workplaces," in *2018 ASEE Annual Conference & Exposition*, *Salt Lake City, Utah, June 24-27, 2018.*

[2] S. Howe, L. Rosenbauer, and S. Poulos, *"*The 2015 capstone design survey results: Current practices and changes over time," *International Journal of Engineering Education,* vol. 33, no. 5, pp. 1393, 2017.

[3] Z. Zhang, H. Liu, L. Chen, Y. Huang, and J. Zhu, “Redesign of capstone design for improving engineering students with multidimensional capabilities,” *in 2020 ASEE Virtual Annual Conference Content Access, Virtual Online, June 22-26, 2020.*

[4] M. Faust, A. Greenberg and B. Pejcinovic, “Redesign of senior capstone program in electrical and computer engineering and its assessment,” in *2012 Frontiers in Education Conference Proceedings*, 2012, pp. 1-6.

[5] M. Cardella, C. Atman, “Engineering students’ mathematical problem solving strategies in capstone projects,” in *2005 Annual Conference, Portland, Oregon, 2005,* pp. 10.559. 1-10.559. 14.

[6] S. Howe, R. Lasser, K. Su, and S. Pedicini, “Content in capstone design courses: Pilot survey results from faculty, students, and industry,” in *2009 Annual Conference & Exposition,* 2009, pp. 14.364. 1-14.364. 34.