ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

ASEE ROCKY MOUNTAIN SECTION CONFERENCE 2023

The Path to Improving the Capstone Course

Abolfazl Amin

I am an Associate Professor in the Mechanical Engineering program of the Engineering department at Utah Valley University. I have 33 years of teaching experience at the university level. My areas of interest are Thermal Sciences, Machine Design, and Advanced Manufacturing. My hobbies are all kinds of sports.

Israd Jaafar

Abdennour Seibi

Prof. Abdennour is a member of ASME and SPE. He received his BS in Mechanical Engineering, MS, and Ph.D. in Engineering Mechanics at Penn State University. He is a distinguished researcher in problems related to the energy sector and advanced materials. He has published over 150 technical papers and 30 technical reports which earned him international recognition from ASME and SPE. He is currently a Professor in the Mechanical Engineering program, at Utah Valley University, Orem, UT, USA.

Sean Tolman

The Path to Improving the Capstone Course

Abstract: Utah Valley University established baccalaureate programs in Electrical, Computer, Mechanical, and Civil Engineering in Fall 2018. Due to increasing demands the university has taken immediate steps to provide quality and competitive education to students by employing highly qualified faculty and expanding the laboratory spaces and buildings. Special attention was paid to the needs of programs and curriculum. ABET accreditation was successfully obtained in 2021. It was realized that a very strong Capstone program was needed in each of the four disciplines of engineering. Team-based learning was the core of the Learning Outcomes in Capstone courses as required by ABET. The focus of this paper is on the Capstone course in the Mechanical Engineering (ME) program. Capstone has been taught as ME-4810 and 4820 in two consecutive semesters as three-credit-hour courses. In the past five years practical projects have been assigned to teams of seniors with great success. Each team has been assigned a coach/mentor who has advised and monitored each team's progress. Extreme care was taken in requiring students to use a comprehensive engineering design process, perform correct engineering analysis, use CAD and FEA tools as much as possible, utilize 3D printing and prototyping, perform necessary testing, and implement logical number of iterations as needed prior to making the final product. Some challenges such as lack of space to meet the growing demand and the necessary funding have been encountered. Fortunately, the Engineering College and the University have quickly solved these issues. Students have competed in national ASME and ASE competitions. It has been determined by the faculty that it would be more effective to create a few full-time staff dedicated to determining and coordinating projects and seeking the support of industry.

INTRODUCTION

Capstone projects continue to be a significant part of the undergraduate engineering program. The purpose of the capstone course is to provide students with the opportunity to apply the engineering principles learned throughout their coursework and to implement the design process in solving real-world engineering problems. Our university has been the fastest growing university in the state for the past few years. Prior to 2018 there was only a Pre-Engineering program that offered Associate of Science and Associate of Pre-Engineering degrees. The total number of full-time faculty has grown from four in 2018 to twenty this academic year. To meet the demand and to be able to offer quality education to students and the community, the university and the state devoted a large amount of monetary funds and resources to the department of Engineering. Despite the problems associated with the pandemic the Engineering department has experienced a steady growth in enrollment. Figure 1 shows the increase in enrollment for each discipline and the total number of students in the department from 2018 until 2022. As for the Capstone courses in the Engineering department were concerned, the focus of this paper was on the ME program because it has been the largest program since 2018. The ME program continues to have the maximum number of students compared to other engineering programs. Figure 2 also shows the increasing pattern of the number of students and Capstone teams in the ME program. Students at UVU consist of traditional, nontraditional, first generation, minorities, and students

with full-time employment. However, the experience they gain in industry also adds value to their future profession in engineering.

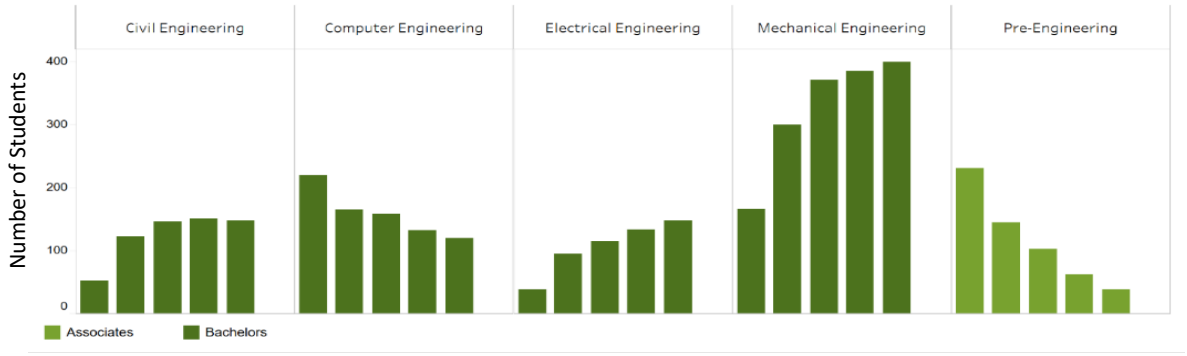

Figure 1: Annual enrollments in the engineering department by discipline from 2018-2022.

Financial aid and scholarships programs provided by the university in addition to having quality programs in engineering could have contributed to the growth. The support from the State Higher Education and local doners have enabled us to take another important step toward establishing a very competitive engineering program by building a new state-of-the-art engineering building. The ground-breaking event will take place in Summer 2023.

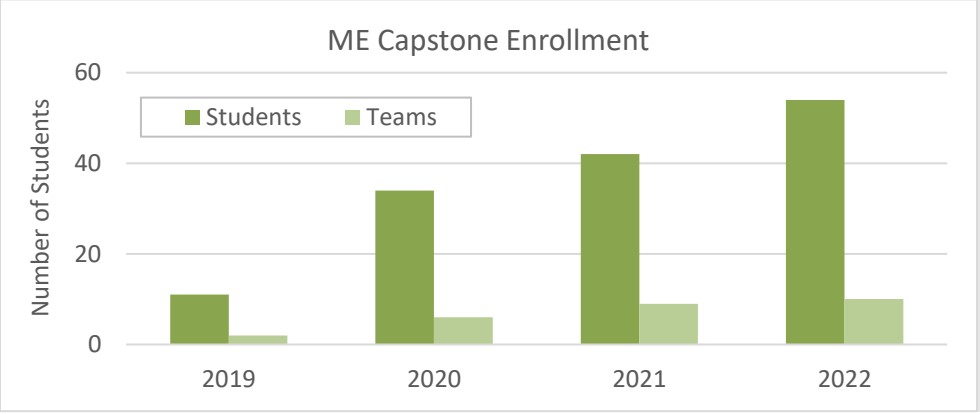

Figure 2: Increases in ME capstone Enrollments since program start.

Each discipline in the Engineering department offers two semesters of senior design or Capstone courses. Students must successfully complete a design project to obtain six credits of Capstone for graduation.

INITIAL CAPSTONE IMPLEMENTATION

The ME Capstone course was created as a two-semester sequence for senior mechanical engineering students. Each course in the sequence is a three-credit hour course which includes a lecture and a lab. The course learning outcomes are shown in Figure 3. One full-time faculty member was assigned to teach the course. The focus of the course is to apply the design process to a real-world engineering problem. Students work in teams of 4-6 members and are assigned a faculty coach or mentor. The lecture part of the class is used to explain the aspects of product design as presented in the Ulrich and Eppinger textbook [1]. The lab portion of the course involves project team meetings and working on project tasks such as design, analysis, and prototyping. Initially, the main assessments for the course were project update reports and design review presentations culminating in final reports and presentations each semester. Due to the small class size for the first year of the capstone program, there were only two project teams. The projects were determined by the course instructor and students were assigned to the teams largely based on their interest in the two projects. The projects were funded by the college and by a university grant awarded to one faculty member. There was only one additional faculty coach or mentor besides the assigned course instructor.

ME Capstone I
By the end of this course students will: 1. Define a design problem and its constraints 2. Develop conceptual design alternatives 3. Use a decision matrix to choose the best solution 4. Identify the development stages through which design evolves 5. Perform validation testing to ensure the desirability and transferability of the design at each stage of the development 6. Apply appropriate concepts to project planning, idea generation, prototyping, modeling and conveying information both in written and oral formats 7. Use effective team processes, communication, and conflict resolution skills 8. Design a product that meets a set of constraints
ME Capstone II
By the end of this course students will: 1. Apply the steps in product realization process to a specific project 2. Function in a team environment to make a project plan and complete the project 3. Write an engineering project report 4. Use effective team processes, communication, and conflict resolution skills 5. Design a product that meets a set of constraints

Figure 3: ME Capstone Learning Outcomes in accordance with ABET requirements.

IMPROVEMENTS TO CAPSTONE METHODOLOGY

Due to growth in enrollments (Figures 1 and 2) and increased number of full-time faculty in the ME program, many changes and improvements have been made to the capstone program. These include changes in project selection, mentoring and funding, refinement of topics covered, and assessment improvements. Projects are currently proposed by faculty or students and then selected by the full ME faculty. Funding for the projects comes from industry sponsors, faculty grants or college funds. Students are assigned projects by faculty based on their project preference and using the CATME team assignment software developed by Purdue University [2]. Each team is assigned a faculty coach or mentor and meets with them weekly to review progress and receive input and feedback on their work. The topics covered in the course have been refined. As mentioned earlier, through the ABET accreditation process, an emphasis on the teaching of codes and standards in the design process was added. Additionally, topics on project management, engineering economics, and intellectual property were included to improve students' professional preparation. Many changes have been made to the assessment of the learning outcomes for the course. In order to gauge student engagement, peer and mentor assessments of student teamwork have been implemented. The peer assessments are done primarily using the CATME system. Also, many individual assignments, quizzes, and attendance points have been included to balance a student's individual effort with scores on team assignments. The primary assessments continue to be through 2-3 design review presentations and a final report; however, these have been improved to include feedback from faculty coaches. The students' grades are largely determined from their team assignments including project update memos, design review presentations, semester reports, and final project evaluations. There are some individual assignments which consist mainly of attendance, reading quizzes and peer teamwork evaluations.

Faculty attend design review presentations or watch them remotely and provide feedback to the teams on their projects. In addition, a public showcase event has been added to allow students to share their projects with the local and university communities as well as industry representatives. Students reports and presentations are assessed through rubrics which are both qualitative and quantitative. They get a numerical score but also receive feedback from faculty on how to improve. We currently use our ABET assessment mechanism to assess the overall success of the course. During the last ABET visit it was recommended to include a section demonstrating how students use codes and standards in their design. The course instructor and team coaches ensure the implementation of codes and standards in their design and construction of prototypes and final products.

LESSONS LEARNED AND FUTURE PLANS

After five years of experience in teaching and coordinating the ME Capstone course, the program has decided to review the pedagogical structure that has been utilized thus far. Maintaining the positive aspects and improving some other issues involved in a course such as Capstone were found to be of utmost importance. Some of the important lessons learned are effective teamwork and mentoring, practical and interesting projects, continuous encouragement of students, be ready to face challenges, students' perseverance, using proper engineering analysis and design process, financial support, and participating in competition could be helpful, but challenging in the meantime. In order to provide a more positive learning experience for students

in their senior Capstone course and to help students apply engineering principles that prepares them for industry, the ME program has the following plans:

1. Establish a full-time team of staff to look for and to direct Capstone projects.
2. Search for industry-supported and funded projects.
3. Seek cooperation from industry to mentor Capstone teams.
4. Look at the possibility and feasibility of assigning projects at the end of the spring semester of students' junior year so that they could think through the problem during the summer prior to the official beginning of their Capstone course.

In conclusion, students and faculty need to be prepared to make such a course as fruitful as possible. New ideas and discoveries could lead to obtaining patents, publishing papers, and presenting at conferences which provide students with very valuable experience in research and development.

REFERENCES

[1] K. Ulrich, S. Eppinger, and M. Yang, *Product Design and Development*, 7th ed., McGraw-Hill Education, 2020.

[2] https://catme.org/login/index