

Advanced Manufacturing Students on Engineering Capstone Design Teams – A First Look

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The Mechanical and Mechatronic Engineering programs at California State University Chico conclude with a common two-semester course sequence in capstone design. Projects are sponsored by industrial partners and all work is accomplished in teams. The first semester focuses on design while the second is dedicated to building and testing a working prototype.

The department also has a new ATMAE accredited program in *Advanced Manufacturing and Applied Robotics* which is graduating about 12 students per year and is growing. Students in that program take the same capstone class as the engineering students and are assigned to project teams based on the manufacturing content of the particular project.

This year's capstone class is made up of 35 mechanical engineering majors, 17 mechatronic engineering majors, and 8 majors in advanced manufacturing and applied robotics. There are 14 projects in the class and 8 of the 14 projects have a single manufacturing student on the team.

All students were surveyed twice about the presence of manufacturing students on capstone design teams, once at end of the design phase and again at the end of the build phase. The survey gathered opinion data from engineering and manufacturing students about the value, contribution, and differing perspectives of manufacturing students on engineering capstone design teams. The survey results paint a generally positive picture with broad agreement that manufacturing students are a valuable asset in both the design and build phases. Interestingly, the second survey showed somewhat less enthusiasm than the first.

Keywords: *Advanced Manufacturing, Engineering Capstone, Teamwork*

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Background

The mechanical and mechatronic engineering programs at California State University Chico have long concluded with a two-semester capstone design course. The intent is for students to utilize competencies developed in the first three years of the curriculum in the solution of a real-world design problem. Projects are primarily sponsored by industry partners, which is consistent with many capstone engineering courses nationwide.¹

During the first semester, twice-weekly lectures are given that cover many aspects of the design process. Selected topics include project definition, conceptual design, decision making, project management, cost estimating, budgets, teamwork, simulation, documentation, and formal reports. Each project group is required to give three oral presentations during the semester, which concludes with submission of a comprehensive design report.

The second semester includes less time in the classroom and more time building and testing the designs. Students develop a comprehensive test plan to prove the engineering specifications developed early in

the first semester. The second semester continues with fabrication and testing, then concludes with a final oral presentation, display of prototype hardware (including a project poster), and submission of a comprehensive written report.

The design projects are accomplished by student groups², as the ability to work in groups is one of the measured outcomes of the course. Groups typically have four to five students, but that may vary based on the complexity of the assigned project. Historically groups have been multidisciplinary with students from both mechanical and mechatronic engineering with the make-up dictated by the technical aspects of the particular project. Regardless, each group is assigned a faculty advisor for the duration of the project, considered by many to be a critical element³ of the student's design experience.

Advanced Manufacturing and Applied Robotics

The college has had a manufacturing program of some sort for more than fifty years. It has been called *Industrial Technology*, *Manufacturing Technology*, then

Sustainable Manufacturing. Due primarily to enrollment challenges, the program was recently redesigned and modernized and is now known as Advanced Manufacturing and Applied Robotics (AMAR). The manufacturing programs have historically concluded with a one-semester capstone tooling class, but in the recent curricular redesign, it was decided that AMAR students would take the same two-semester capstone class as the engineering students and would be added to design teams based on the manufacturing content of the particular project.

The new program has three primary areas of emphasis as applied to Advanced Manufacturing: robotics and automation; materials and manufacturing processes; and business, communication, and management. The program emphasizes project-based learning where students apply fundamentals to solve real-world problems and develop teamwork skills. Graduates of this unique, multidisciplinary program are fully prepared to become leaders in the dynamic manufacturing industry. The program graduates about 10 students per year and is growing rapidly.

This year’s capstone class enrolls 35 mechanical engineering majors, 17 mechatronic engineering majors, and 8 majors in advanced manufacturing and applied robotics (AMAR). There are 14 projects in the class and 8 of the 14 projects have a single manufacturing student on the team.

The Survey

A survey was developed to gather student opinion data about the presence and effectiveness of advanced manufacturing students on engineering design teams. The survey was administered twice, once at the end of the design phase and again at the end of the build phase. The first survey was completed by 57 of 60 students including all 8 manufacturing majors. The second survey was completed by 53 of 60 students including all 8 manufacturing majors. All results are shown as a percentage. The first column (blue) represents the first survey (after the design phase) and the second column (orange) represents the second survey (after the build phase).

Preliminary questions established the students’ major and whether or not their team included an advanced manufacturing student. The first question of the first survey was addressed to everyone in the class. It asked: “Using a Likert scale where 5 = Strongly Agree and 1 = Strongly Disagree, please answer the following question: *I expect that having a manufacturing student on my capstone team will be (or would have been) a great asset during the design phase of our project.*” The wording for same question in the second survey was changed slightly to *Having a manufacturing student on my capstone team*

was (or would have been) a great asset during the design phase of our project.

The results shown in Figure 1 show fairly strong agreement with the idea of manufacturing students on capstone teams during the design phase. A change between the first and second surveys shows greater agreement and less neutral responses.

Question 2 asks the same questions except for the fabrication phase. The results shown in Figure 2 show even stronger agreement with little change between the two surveys.

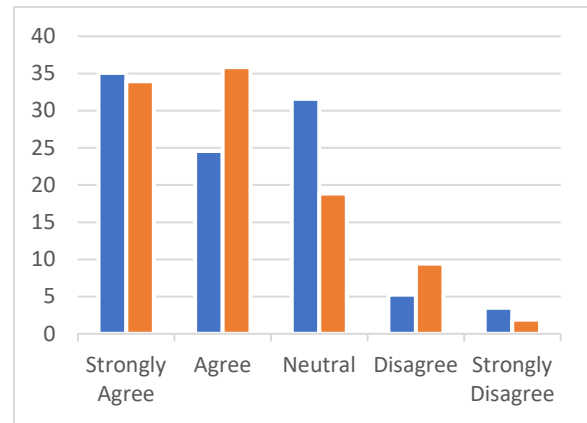


Figure 1 – Manufacturing Students are a Great Asset During the Design Phase

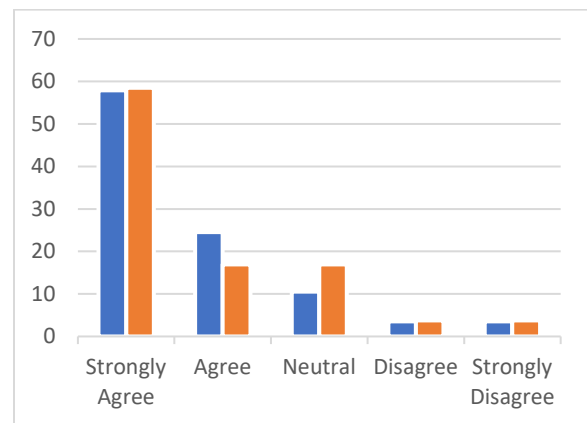


Figure 2 – Manufacturing Students are a Great Asset During the Fabrication Phase

All remaining questions were identical for the two surveys. The next two questions were addressed only to engineering students on capstone teams that included an advanced manufacturing major. Question 3 asked for agreement to the statement: *The manufacturing student on my capstone team brought a different and valued perspective to the project.* The results shown in Figure 3

show a mostly positive outcome but with a noticeable decrease in agreement from the first survey to the second.

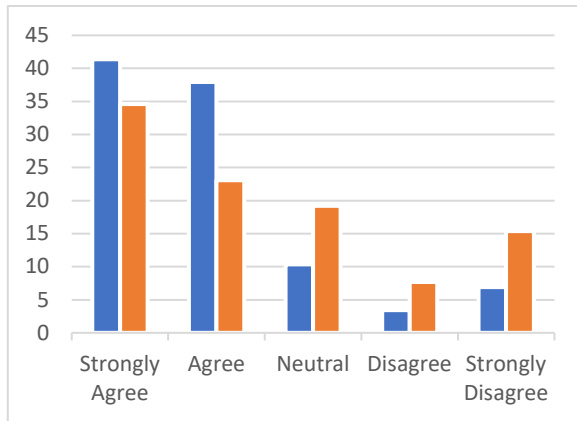


Figure 3 – Engineering Students: Manufacturing Students Bring a Different and Valued Perspective

Question 4 asked the engineering students for agreement with the statement: *I think having manufacturing students on capstone teams is a great idea, as it adds the real-world element of working with people from different disciplines, as will likely happen in industry.* The results in Figure 4 show strong agreement after the design phase but a noticeable shift to general agreement after the build phase.

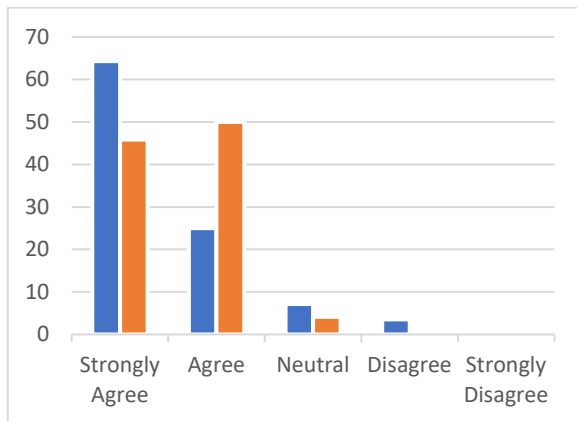


Figure 4 – Engineering Students: Manufacturing Students on Capstone Design Teams is a Good Idea

The remaining questions were addressed only to manufacturing students. Question 5 asked for agreement to the statement: *As a manufacturing student, I feel I bring a different and valued perspective to the project.* The results in Figure 5 show that most but not all manufacturing students feel that they bring different perspectives that have been valued. But once again, there was a noticeable shift to the right in the data.

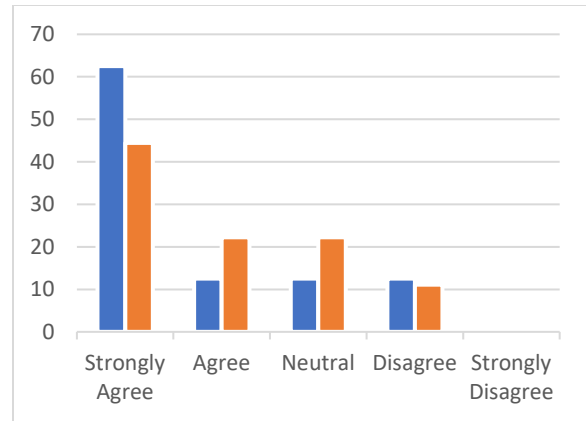


Figure 5 – Manufacturing Students: We Bring a Valued Perspective to Capstone

Question 6 asked manufacturing students for their agreement to the statement: *As a manufacturing student, I feel that my engineering teammates value my background and the different perspective and skillset that I bring to the team.* The results are shown in Figure 6 which show solid agreement with little change from the design phase to the build phase.

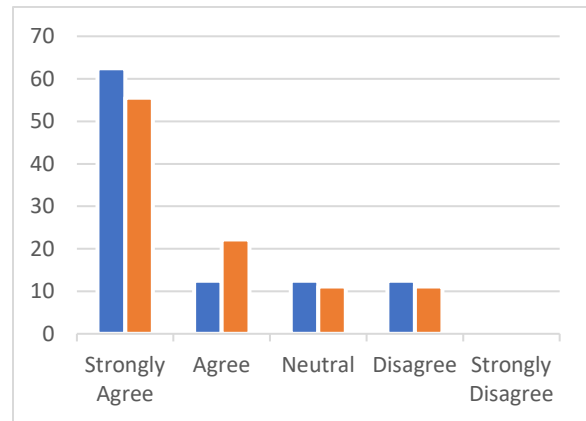


Figure 6 – Manufacturing Students: We Feel Valued by Our Engineering Teammates

The intent of the two similar questions was to tease out any differences between the manufacturing students' own view of the perspective they bring to the team versus their perception of the view of the engineering students. It is interesting to note that the manufacturing students feel that they are valued by the engineering students to largely the same degree that they themselves feel they are valued.

The 7th and final question addresses the difference between the legacy manufacturing programs and the new program with regard to its capstone experience. It asked for agreement to the question: *As a manufacturing major,*

I'm glad that the AMAR program concludes with a capstone experience working with engineering students on real-world, externally sponsored projects. It is a much better learning experience than a manufacturing-only capstone class. The results shown in Figure 7 show that six of the eight manufacturing students in the class value the experience, one is neutral, and one clearly does not.

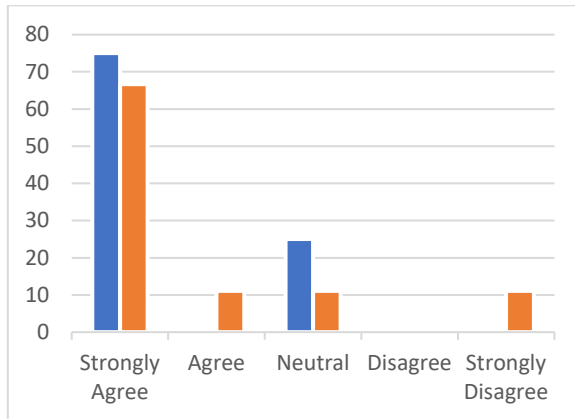


Figure 7 – Manufacturing Students: We Prefer Capstone Alongside Engineering Students

Two free response questions were included to solicit comments. Engineering students with manufacturing students on their teams were asked: *Please add any comments based on your experience of having a manufacturing student on your capstone team.* Similarly, manufacturing students were asked: *Please add any comments based on your experience of being a manufacturing student on a multi-disciplinary capstone team.*

The comments have been broken down into themes that were consistent across both surveys. Selected comments that typify each theme are included below.

Engineering Student Theme – Positive Reaction

- *The AMAR student on my team was great with machining, assembly, cutting materials, choosing, choosing fasteners and Solidworks. They gave valuable insight during the design phase into what's actually possible and doable.*

Engineering Student Theme – Negative Reaction

- *Most of the manufacturing for our project ended up happening through a 3rd party due to time constraints and little machining happened on campus. Designing for machinability was a much smaller portion of the design process than designing with engineering specs.*

Manufacturing Theme – Positive Reaction

- *I was able to contribute meaningfully not only to the design and general fabrication of the project, but also to the testing and assembly phase where rapid adjustments and modifications had to be made. I feel valued by my team, and also glad to be working with an interdisciplinary team that can make up for gaps in my own knowledge base.*
- *As someone who wants to be a bridge between engineering and manufacturing, I am finding this experience to be extremely valuable. I would feel very disappointed if I was not involved in a capstone that had AMAR and Engineering.*

Manufacturing Theme – Negative Reaction

- *It's hard sometimes because I am able to add my input involving manufacturability of our project but due to the major coursework, I don't understand a lot of math above pre-calc or FEM.*

Conclusion

This first look at student perspectives of manufacturing students on engineering capstone design teams shows a generally promising picture with broad agreement (Figures 1 & 2) from all students that manufacturing students are a valuable asset in both the design and build phases. Figures 3 & 4, answered by engineering students with a manufacturing major on their team, show general approval of the notion but the data show a noticeable retreat of enthusiasm after the build phase of the project. Figures 5 & 6 show that manufacturing students generally feel that they bring a valuable perspective and that it is appreciated by their engineering teammates. But again, both figures show a noticeable drop from the design to the build phase. Finally, Figure 7 shows that 75% (6 out of 8) of the manufacturing students prefer this sort of capstone experience, though the sample size is admittedly small.

References

1. Latorre-Navarro, E. L., Groll, E. A., Thompson, S. M., and Hirlman, E. D., 2020, "Capstone Course Industry Sponsor Assessment," Proceedings of the Capstone Design Conference (CDC 2020), Virtual Conference
2. Mynderse, J. A., et al., 2021, "Assessing ABET Student Outcome 5 (Teamwork) in BSME Capstone Design Projects," Proceedings of the ASEE Annual Conference
3. Watkins, G.K., 2011, "Best Practices for Faculty Mentorship of Capstone Design Projects," Proceedings of the ASEE Annual Conference