

The Use of Project Type Tracks, Scaffolding and Websites in a Large and Multi-Disciplinary Capstone Design Course

Javier Calvo-Amodio, Tracy A. Robinson and John P. Parmigiani
Oregon State University

When a capstone course is run in a large and multi-disciplinary environment, the nature of the projects will vary. Such is the case at the School of Mechanical, Industrial and Manufacturing Engineering at Oregon State University where at least 40 different capstone projects are run in a given cycle. The projects range from industry-based to research-based and student competition-based and include the design of both products and processes. To manage such a large, multi-disciplinary course and to ensure that course expectations are communicated clearly to students, the course instructors have developed three strategies: (1) standardized “tracks” to accommodate three distinctly different project types; (2) a “scaffolded” project completion process; and (3) a custom-built web-based tool that facilitates communication and information flow between team members, project advisors and sponsors, and course instructors. In this paper, the authors describe and discuss these strategies.

Keywords: multi-disciplinary projects, large courses, mechanical engineering, industrial engineering, manufacturing engineering, student competitions, scaffolding

Corresponding Author: Javier Calvo-Amodio, Javier.Calvo@oregonstate.edu

Introduction and Background

Students in Oregon State University’s School of Mechanical, Industrial, and Manufacturing Engineering (MIME) have two options for their two-term (20-week) capstone experience. All students take the same basic course (ME/IE 497-98), but they may enroll either in an automotive engineering section, in which students design and manufacture vehicles for the annual Formula and Baja SAE competitions, or they may take the “general” section that offers a much wider variety of design projects, about 70% of which are industry-sponsored. Both sections are open to all MIME majors and have the same learning outcomes, albeit with some variations on how the outcomes are delivered. Because MIME Capstone Design is the designated writing-intensive course for MIME majors (a university-wide baccalaureate core requirement), both sections also include a substantial emphasis on written and oral communication skills.

This paper focuses on the general section of MIME Capstone Design, which since 2005 (the first year the current version of the course was offered) has included the following basic features:

- The design projects are all scoped for three-person project teams and a 20-week project completion time frame.
- As already noted, most of the projects are sponsored by industry. The rest come from community

organizations, university researchers, and OSU student chapters (e.g., ASME and AIAA) involved in national and international competitions.

- Project selection is based on a bidding process.
- Project completion follows a seven-step design process: Identify customer needs; perform background research; generate project requirements and specifications; generate multiple solutions; analyze those solutions to select the most viable; complete a detailed design; and implement and test the design.¹ The project report documents each of these steps.
- As described in Sherrett and Parmigiani (2011)² students use the house of quality (HoQ) – a tool first introduced in 1972 at Mitsubishi’s Kobe shipyard and further developed by Toyota³ – as their cornerstone for design development.
- In addition to receiving instruction and project oversight from the course instructors, all project teams are assigned an advisor (MIME faculty member or graduate student with relevant expertise) who serves as a technical consultant and participates in project evaluation and report grading.⁴
- The general section curriculum satisfies the OSU Writing Intensive Curriculum course specifications, which include (among other things) the use of discipline-specific graded and ungraded writing assignments and of substantive feedback-and-revision cycles.⁵

In 2005, when the features listed above were first implemented in the capstone design general section (within OSU's then-department of mechanical engineering), the course enrollment was around 64 students and included only ME majors. The industrial and manufacturing engineering department ran its own version of a capstone class. The subsequent 2007 merger of OSU's mechanical, industrial and manufacturing engineering programs into the School of MIME led to the formation of a combined, multidisciplinary capstone design course that continued to utilize the core course structure described above but now included all MIME majors and therefore needed to offer projects with relevancy to all majors. Moreover, as a result both of the ME-IME merger and of escalating program enrollments in recent years, the general-section course size has more than doubled since 2005; the 2013-14 MIME Capstone Design general section included 135 students and 45 projects.

In the face of this much larger class size and wider project typology than the course was originally designed for, maintaining the integrity of the core curriculum and quality of course assessment, and continuing to provide all students with a rigorous, comprehensive, and relevant capstone design experience – complete with a writing-intensive focus – has become a challenging task.

This paper discusses three course-management strategies that the current instructional team (an industrial and manufacturing engineering faculty member, a mechanical engineering faculty member, and the School's communications specialist) has adopted to help meet this challenge: (1) standardized "tracks" to accommodate three distinctly different project types; (2) a "scaffolded" project completion process; and (3) a custom-built web-based tool that facilitates communication and information flow between team members, project advisors and sponsors, and course instructors.

Although these strategies are still in the development phase and will undergo further refinement in the coming years, preliminary assessment data and student feedback indicate that their incorporation has been beneficial for MIME Capstone Design and may also be generalizable to other large, multidisciplinary capstone courses.

Standardized Project Tracks

While the seven-step engineering design process noted in the introduction is universally applicable, the approaches to some of those steps and times spent on the various design phases can vary considerably among different project types. For example, the product-based projects most commonly associated with mechanical engineering usually involve the design of a new device or system, have well-defined outcomes and scopes, and require substantial time and effort in the manufacturing phase.

Student-team competition-based projects, while in many ways almost identical to product-based projects, must also abide by stringent competition requirements, often build upon the knowledge and experiences from previous years' competition entries, and require ongoing interaction with the sponsoring student chapters. For both product- and competition-based projects, the origins of the design problem are usually fairly straightforward at the start, and the path to the solution is clear. With the process-based projects that are commonly associated with industrial engineering, however, usually only the general problem is known at the start. Prior to designing a solution to the problem, the design team must perform extensive analysis to identify and validate its source.

Given these differences, the design-phase time frames and relevant documentation will also vary by project type. For example, in a single-team process-development project, the customer requirements, engineering requirements and testing procedures may not be fully defined until well into the second term of the course, whereas a design team tasked with designing one aspect of a student competition entry, as part of a larger multi-team collaboration, usually needs to identify all project requirements and testing procedures before the end of the first term.

So while we originally attempted to use a one-size-fits-all design development schedule, report template, and grading approach for all MIME project types, the need for greater flexibility soon became clear. The course therefore now includes three project tracks – product, process, and competition – each with its own set of evaluation criteria and report template.

Course Scaffolding

Echoing and reinforcing the iterative nature of the engineering design process, the curricular infrastructure of MIME Capstone Design includes multiple "check-in" points and processes to support project success, as listed below and shown in Figure 1.

- The "linked" project specifications documented in the HoQ – customer requirements, engineering requirements, and testing procedures – are developed in three phases, and each set of specifications requires instructor, advisor, and sponsor review and sign-off. This iterative approach to specifications development greatly reduces the chances of under- or overestimating design capabilities, misinterpreting what the sponsor expects from the team, etc.
- Project status meetings scheduled at 3-week intervals provide another opportunity to monitor progress and "steer" project teams that are veering off course.
- To discourage procrastination during the implementation phase and ensure sufficient time for prototype testing and improvement prior to course

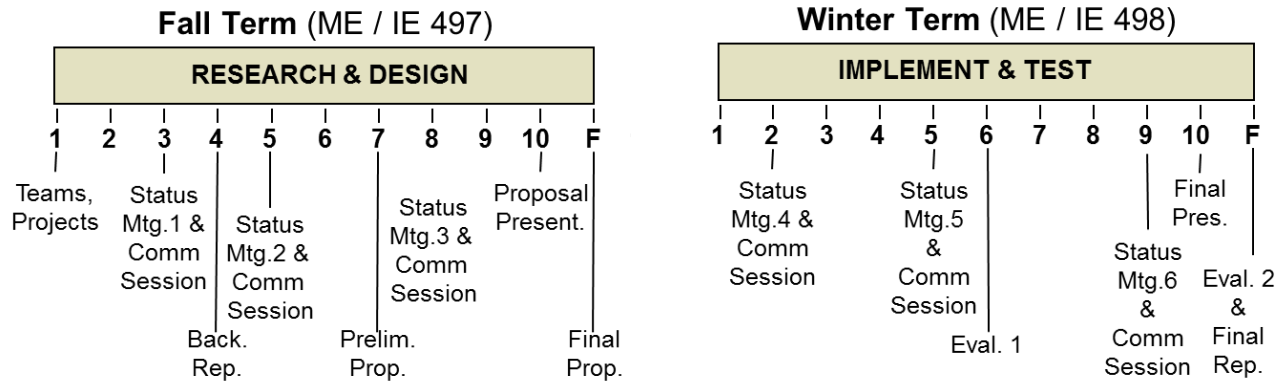


Figure 1. Scaffolding Course Design

conclusion, a high-stakes “testing readiness” check-in is conducted during week 17.

- Finally, sequential development of the project report is also an important scaffolding element. Students complete the report in four iterations – background report, preliminary, final proposal, and final report – each of which refines and builds on the previous iteration.

Expanding on the last bullet point above, the sequential report development strategy was originally developed to allow for the feedback and revision cycles required for all OSU writing-intensive courses; and multiple opportunities for writing-skills development do of course lead to much higher-caliber final reports than would be produced in a “one-shot” approach. Additionally, however, the iterative report development approach also contributes to better project results because the report review cycles serve as opportunities for project advisors and instructors to gauge the quality of students’ critical thinking about their projects and their understanding of the course expectations and requirements. In some cases, the report content reveals a need to provide additional instruction and clarification on these matters.

Additionally, because the report feedback addresses not only writing quality but also technical content, students are pushed to clarify their understanding of the project objectives, do additional background research, better justify their design selections, and other efforts that ultimately lead to higher-quality project results. Thus (and despite students’ complaints that “all this writing keeps us from focusing on our actual projects”), the iterative report development approach also promotes a better capstone experience overall.

Web-based Communications Interface

Two of the biggest logistical challenges associated with large class sizes in project-based courses are information

and deliverables tracking and communication among project stakeholders (project sponsor, project advisor, class instructors and student team members). As previously stated, the experience for each team may differ substantially from others, making it a challenge to maintain a level of consistency in the design experience for all stakeholders involved.

In the past, Blackboard™ and a publicly accessible website have been used for posting course information, assignments, lecture slides, and other resources. But neither of these venues provided an appropriate mechanism to promote and maintain a mentoring structure and an open communication channel for all stakeholders.

For that reason, a Web-based platform was designed. Google was selected because OSU student and faculty accounts are linked to Google sites and drive. Each project is assigned a separate website to which only the team members, advisor, sponsor mentor, and course instructors have access (via Google groups), but all project websites shares the same skeleton structure.⁶ The course instructors post all project-relevant course documents and materials (templates, rubrics, lecture notes, etc.) on the websites, and project team members are required to post all of their project-specific documents (team charter, reports, HoQ, etc.) on their individual sites. They are also strongly encouraged to use their site for intra-team communication and collaborative document development.

Conclusions

Figure 2 on the following page presents a conceptual map depicting the course structure after integration of the tracks, scaffolding and web-based platform. The new structure has proven to increase the students’ performance in and satisfaction with the course and hence the quality of their project results. Preliminary results for the implementation of this approach after just one year are reflected by a 5% increase in students’

average course grades and a 10% increase in students' instructor evaluation scores.

Preliminary informal evidence based on instructors' observations of project teams' performance, informal comments by students, and instructor evaluations indicates that the course structure presented in this paper has made a positive impact on the students' experience. It is worth noting that, as stated by McGrath (2014),⁶ the engineering design process has "been made more efficient and easier to follow" as a result of the implementation of the approaches described in this paper.

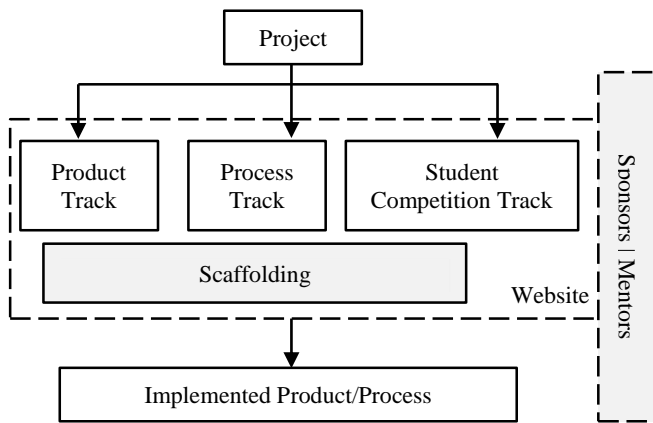


Figure 2. MIME Capstone Design Course Structure

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