

AC 2007-2375: SUCCESS STRATEGIES FOR CAPSTONE DESIGN COURSES WITH LARGE CLASSES, DIVERSE PROJECT TYPES, SMALL TO LARGE STUDENT TEAMS, AND VARIED FACULTY INTERESTS AND APPROACHES

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Success Strategies for Capstone Design Courses with Large Classes, Diverse Project Types, Small to Large Student Teams, and Varied Faculty Interests and Approaches

Abstract

Capstone design courses are a core part of curricula across engineering disciplines. Such courses offer students the opportunity to bring together, assimilate and apply the knowledge they have acquired over their entire undergraduate academic program. Projects are often real world problems that are less well specified than those encountered in prior courses and may challenge student teams beyond familiar bounds required of less challenging projects. Identifying projects, recruiting faculty advisors for projects, and providing meaningful class lectures to seniors that will be both interesting and useful to successful projects are typical challenges of such courses. Numerous other challenges emerge when the class size is large. During the 2006/07 academic year, there are over 280 seniors enrolled in the 2-semester capstone design course sequence in the Department of Mechanical Engineering at Virginia Tech. This paper will convey the wide variety of challenges and provide specific strategies that have been used for success in an environment where 1) the types of projects are very diverse in terms of difficulty, application domain, and scope, 2) team sizes vary from 4 members to over 30 members, and 3) the interests and approaches of faculty advisors are quite varied.

Background and Motivation

The capstone senior design course sequence, ME 4015 – 4016, includes more than twenty-five different projects, with nearly as many different faculty advisors. The course sequence also offers our students several different project options: design projects closely connected to funded research, or projects proposed and sponsored by private industry, and yet others that involve national and international competitions. Such diversity is one of the course strengths, giving students a choice in their design experience. Recognizing the diversity among our design projects, it is important for all of our students to achieve, in the course of their senior design experience, a consistent set of course objectives, regardless of the project they select. To achieve a degree of consistency among our senior design projects, while embracing the diversity of our projects, a new policy has been developed that includes a set of common course objectives, deliverables, and evaluation practices. A committee of 6 faculty members representing experiences with large teams, small teams, competition teams, industrially sponsored teams, the course coordinator, and undergraduate program director for Mechanical Engineering participated in the development of this new policy for our senior design course sequence. The following sections describe the new policy, course format and procedures, and support provided to students and faculty.

Course Policy for ME 4015 – 4016 Sequence

The course policies for ME 4015 and ME 4016 are presented below in four policy subsections:

- A. Major Measurable Learning Objectives
- B. Course Format and Procedures
- C. Course Deliverables
- D. Grading Policy

A. Major Measurable Learning Objectives (4015-4016)

Having successfully completed ME 4015 and ME 4016, students will be able to design mechanical and/or thermal systems using engineering, science, and mathematical methodologies including but not limited to, the following:

1. Knowledge of and skill with the design process including
 - a.) problem recognition and definition
 - b.) establishment of design requirements (performance and life-cycle, such as economic, manufacturability, assemblability, usability, aesthetics, quality, serviceability, sustainability, as well as impact in an environmental, societal, and/or global context)
 - c.) generation of multiple design concept alternatives
 - d.) utilization of decision-based methods and tools to support analysis, evaluation, and selection of design alternatives against multiple and perhaps conflicting requirements
 - e.) analysis and verification of the design throughout the various stages of the process, leading to a product that is validated against design requirements
2. Design systems in a team environment where multiple disciplines or ME specialty areas are used.
3. Understand the ethical responsibilities associated with the mechanical engineering profession.
4. Prepare formal written design documentation (e.g. memos and technical reports) and present effective oral presentations.
5. Utilize a variety of sources in researching the field(s) and concepts appropriate to the design and benchmarking (e.g : US Patent and Trademark Office, vendor catalogs, Thomas Register, library, and Internet).
6. Utilize modern engineering and computer tools.

B. Course Format and Procedures

ME 4015

ME 4015, the first semester of Capstone Senior Design, includes a once-per-week, required lecture and a separate required project team meeting that also occurs at least once per week, during the Fall semester. Instructional responsibility is shared between the course coordinator (lecture) and faculty advisor (project team). The lecture and the project team meetings are together used to achieve the course objectives and both are used to determine the final grade in ME 4015 for each student. The lectures cover a broad range of design related topics, many of which have direct relevance to the team projects, but also include more general topics such as design methodology, professional ethics, and economics, among others. The project team activities that are used to meet the course objectives are determined by and under the direction of the faculty advisor. Guidelines are provided to the faculty advisors, in keeping with the

requirements of the mid-term and end-of-term reports. The final grade for the students in ME 4015 is determined by a weighted score based upon performance in (1) lecture, (2) project team activities, (3) the midterm report and presentation, and (4) final, end-of-term report and presentation (see section C on ME 4015 Deliverables, below).

ME 4016

ME 4016, the second semester of Capstone Senior Design, requires a formal project team meeting that occurs at least twice per week during the Spring semester. The faculty advisor to the team is responsible for the team meetings and the team's progress. Guidelines are provided to the faculty advisors, in keeping with the requirements of the mid-term and end-of-term reports, the end-of-term presentation and poster session. The final grade is determined by a weighted score based upon performance in (1) project team activities, (2) mid-term report and presentation, (3) end-of-term report and presentation, (4) product realization, and (5) end-of-term poster (see section C on Deliverables for ME 4016, below).

C. Deliverables

ME 4015

For ME 4015 the course deliverables associated with the measurable objectives are divided among:

- (1) the lecture and associated assignments,
- (2) design team activities/assignments,
- (3) the midterm report and oral presentation and
- (4) the end-of-term written project report and oral presentation.

(1) Lecture deliverables.

Graded assignments in the lecture may include in-class quizzes or exercises, as well as homework. The course coordinator is responsible for preparing, assigning and grading the lecture assignments. Many of the assignments are directly associated with the students' design project and contribute toward the mid-term and end-of-semester reports. Others are related to the lecture topics and the major measurable learning objectives listed previously.

(2) Design team activities and deliverables.

Assignments associated with design team activities are determined and graded by the faculty advisor. However, a minimum set of deliverables is required including: individual logbooks, a design binder, and written memos or progress reports. Additional deliverables as determined by the individual faculty advisor may also be required. The faculty advisor will evaluate individual team member's project assignments and, at the end of the semester, provide the 4015 course coordinator with each team member's score.

(3) Mid-term report and presentation.

The midterm deliverable includes both a written report and an oral presentation with a question and answer period. The midterm written report is a design proposal to be evaluated by the faculty advisor and the course coordinator. A formal oral presentation of the design proposal is also required and is evaluated by the faculty advisor. During the oral presentation all students on the design team must present material and all students should be prepared for the question period at the end of the presentation. Guidelines for the content of the design proposal are provided.

(4) End-of-term report and presentation.

The final deliverable for ME 4015 is a written design report and an oral presentation. The report is an update of the midterm report now including a description of the proposed design, specifications, justification of choices with analysis to support the concept, and a plan for the Spring semester. Again, guidelines for the final design report for ME 4015 are provided to the faculty advisor and the project teams.

The final written report is evaluated by the faculty advisor to the team and the course coordinator. The faculty advisor evaluates the final presentation. However, the final presentation is open to the public and is evaluated by the faculty advisor with input from a panel that may include the course coordinator, other faculty, graduate students, and industry visitors. The score of each design team member is based upon each member's participation and performance. The faculty advisor and panel are given guidelines to aid in the evaluation of the team presentation.

ME 4016

The course deliverables for ME 4016 are associated with the measurable objectives and are divided among:

- (1) design team activities/assignments,
- (2) the midterm report and oral presentation,
- (3) the end-of-term written project report and oral presentation,
- (4) the end-of-term product realization.
- (5) the end-of-term poster and poster session.

(1) Design team activities and deliverables.

Assignments associated with design team activities are determined and graded by the faculty advisor. Continued contributions to individual logbooks, a design binder, and written memos or progress reports are expected. The faculty advisor evaluates individual team member's assignments and, at the end of the semester, provides the course coordinator with each team member's score. Grades for all 4016 sections are assigned by the course coordinator (the same coordinator as ME 4015), based upon the scores provided and they are assigned consistently for all students in ME 4016 (refer to section D, Grading Policy).

(2) Mid-term report and presentation.

The midterm deliverable includes both a written report and an oral presentation with a question and answer period. The midterm written report and oral presentation serves as a design review/progress report to be evaluated by the faculty advisor. The course coordinator provides guidelines on the written report. During the oral presentation all students on the design team must present material and all students should be prepared for the question period at the end of the presentation.

(3) End-of-term report and presentation.

A final written design report and an oral presentation by the design team are required in ME 4016. Guidelines for the final design report are provided to the faculty advisor and the project teams. The final written report is evaluated by the faculty advisor to the team and the course coordinator. A panel

including the faculty advisor, the course coordinator, another ME faculty member and an invited guest evaluates the final presentation. Each member of the design team is evaluated by the panel based upon the design team member's participation and performance. The evaluation panel is given guidelines to aid in the evaluation of the team presentation.

(4) End-of-term product realization.

It is expected that all projects will result in a "product" that is demonstrated to meet the design requirements. This final design product can be presented during the end-of-semester oral presentation or in a separate demonstration (if appropriate). All "products" will be showcased and discussed at a poster session. The final design product is graded by the faculty advisor with input from a panel again that includes the course coordinator, a ME faculty member, graduate students and an invited guest. Product realization will be a team score.

(5) End-of-term project poster and participation in the poster session.

At the end of the Spring semester each design project team prepares a technical poster reviewing the design task, process, and final design. Guidelines for the preparation of the poster are provided. A poster session, open to the public and including all projects, is held at the end of the semester. The posters are graded by the course coordinator with input from a panel. As mentioned in (4) above, all "products" are showcased and discussed at the poster session. The panel includes the faculty advisors, graduate student teaching assistants and if available, ME Advisory Board members and other invited guests. The poster and session participation is a team score.

D. Grading Policy

ME 4015

The final grade in ME 4015 is assigned by the course coordinator. Scores on the various deliverables are provided to the course coordinator and the grades assigned appropriately and consistently for all students enrolled in ME 4015. The grading policy is as follows:

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| 1. Course lecture assignments and quizzes, Course Coordinator | 15% |
| 2. Design team activities and deliverables, Faculty Advisor
(may include: individual logbooks, design binder, written memos, progress reports, peer evaluations, hours reported, etc.) | 35% |
| 3. Midterm deliverable | 25% |
| 10% presentation, Faculty Advisor | |
| 15% written report, Faculty Advisor (10%) and Course Coordinator (5%) | |
| 4. End-of-term deliverable | 25% |
| 10% presentation, Faculty Advisor with input from panel | |
| 15% written report, Faculty Advisor (10%) and Course Coordinator (5%) | |

As described previously, the midterm report is evaluated by the faculty advisor and the course coordinator. The midterm presentation is evaluated by the Faculty Advisor. The end-of-term report is evaluated by the faculty advisor and course coordinator; however the end-of-term presentation is evaluated by the Faculty Advisor with input from a panel (which may include other faculty, course coordinator, graduate students and invited guests).

ME 4016

The final grade in ME 4016 is assigned by the course coordinator (the same coordinator for ME 4015). Scores on the various deliverables are provided to the course coordinator and the grades assigned appropriately and consistently for all students enrolled in ME 4016. The grading policy is as follows:

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|---|-----|
| 1. Design team activities and deliverables, Faculty Advisor
(may include: individual logbooks, design binder, written memos, progress reports, peer evaluations, hours reported, etc.) | 30% |
| 2. Midterm deliverable
10% presentation, Faculty Advisor
15% written report, Faculty Advisor (15%) | 25% |
| 3. End-of-term deliverable
10% presentation, Faculty Advisor with input from panel
15% written report, Faculty Advisor (10%) and Course Coordinator (5%) | 25% |
| 4. Product realization, Faculty Advisor with input from panel | 15% |
| 5. End-of-term poster Course Coordinator with input from panel | 5% |

As described previously, the midterm report and presentation are evaluated by the faculty advisor. The end-of-term report is evaluated by the faculty advisor and course coordinator; however the end-of-term presentation and product realization are evaluated by a panel consisting of the faculty advisor, course coordinator, a ME faculty member and an invited guest. For the poster and poster session, the course coordinator provides the evaluation with input from a panel that includes the faculty advisor, graduate teaching assistants, an invited guest and, if available, ME Advisory Board members.

Support for the Administration of Policies and Working with Faculty and Students

The administration of these policies and working with faculty and students was facilitated with weekly meetings between the course coordinator, faculty project advisors and graduate teaching assistants supporting the course lecture and projects. It was also facilitated through use of the electronic Blackboard™ course administration system.

The weekly meetings were an open forum to discuss upcoming lecture topics, communicate the status of progress of the student projects, discuss challenges and opportunities and coordinate assignments and due dates. Lecture topics were planned in a sequence to match, as best as possible, the anticipated needs of project teams as they proceeded through the design process. Topics include: overview of design process, project planning, requirements, House of Quality, shop safety, concept generation, concept evaluation and selection, ethics, and professionalism. Several industry guest lectures on design process and methods were also included during the once-per-week lecture sequence.

All lecture materials and assignments were posted on the course Blackboard. Regular e-mails were also sent out to faculty, graduate students, and students enrolled in the course.

Conclusions and Future Work

We are in the early stages of administering the course according to the new policy. The first semester of the 2-semester sequence is completed. We are in the process of analyzing the data to

evaluate the impacts of the changes to student learning, quality of design projects and overall experiences of all faculty advisors involved. Early indications are that the consistency in learning outcomes and expectations has positively impacted many students and their senior design experience. There are other improvements being incorporated in the second semester of the course sequence in the current semester, such as the final poster display, that will also be evaluated at the conclusion of this semester. We plan to showcase these results and the final products and lessons learned at the time of the ASEE conference and in upcoming publications.