Capstone Courses – An Engineering Perspective

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Areas for Discussion

• Context of engineering capstone courses
• Curriculum and capstone courses
• Reports, expectations, and assessment
• Role of faculty
• Examples of some projects
• Lessons learned (often several times)
The efforts I will discuss are due to many faculty in three departments:

- BME: Eberhardt
- MSE: Andrews, Janowski, Vaidya, and (Thompson)
- ME: Oliver and (Stephens) with a recent additions of McInerny and Simionescu

These classes have been taught by many people but we try to stay parallel and learn from each other.
Context of Engineering Capstone Courses
Capstone Courses in Engineering

Accredited engineering programs must have a capstone design experience. The part of the Criterion reads:

Students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints.

There is a long history of “senior design” or “senior project.”

In 2000, a major change in the accreditation process occurred:

- Went from a “we taught it” to a “they learned and we can measure and document it” philosophy
- Established general and discipline-specific Outcomes that all graduates must accomplish, many of which are “soft-skills”

The changes in accreditation criteria changed Senior Design.
Engineering Design – ABET Definition

“Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs.”

Engineering capstone courses cannot be research projects – the design/science and definitions have been a problem for “sciency” programs.
Curriculum and Courses
Engineering Curricula (MSE Example)

Very prescriptive and prerequisite driven:

- 31 credits of mathematics (calculus-differential equations) and basic science (chemistry, physics)
- 24 credits of Humanities and Social Science (EH 101, EH 102, 9 credits of Area II, 9 credits of Area IV)
- 24 credits of basic engineering (drawing, statics, statistics…)
- 43 credits of required MSE courses (5 in Senior Design)
- 3 credits of MSE elective
- 3 credits of Engineering/Mathematics/Science elective

Curriculum leads to graduates achieving Program Outcomes
Materials Engineering Outcomes – Mathematics, Science and Engineering

Graduates will:
1. be able to apply knowledge of mathematics, advanced science, and engineering principles to materials systems.
2. be able to design and conduct experiments, and to analyze and interpret data.
3. understand the fundamental principles underlying and connecting the structure, processing, properties, and performance of materials systems.
4. be able to apply and integrate knowledge from each of the above four elements of the field to solve materials selection and design problems.
5. be able to design a part, component, or process to meet specific needs.
7. be able to identify, formulate, and solve engineering problems.
13. be able to use experimental, statistical, and computational methods to analyze the behavior of materials systems.
Graduates will:

6. be able to function on multi-disciplinary teams.
8. understand professional and ethical responsibility.
9. be able to communicate effectively, both in oral and written forms.
10. have the broad education necessary to understand the impact of engineering solutions in a global and societal context.
11. recognize the need for, and be able to engage in life-long learning.
12. have a knowledge of contemporary issues through an integration of faculty experience gained from research and professional activities into program courses.
Changes in Capstone Courses

The Program Outcomes led to some new ideas or emphases in Capstone courses:

- multi-disciplinary teams – have students from different majors or specializations working together
- communicate effectively – not most engineer’s forte
- impact of engineering solutions – how does what we do affect users? The environment?
- life-long learning – students must be able to self-teach
## Project concept

<table>
<thead>
<tr>
<th>We give them</th>
<th>They start with</th>
<th>They develop/use</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Defined Problem with constraints and a challenge in each discipline</strong></td>
<td>Mathematics and Basic Sciences</td>
<td>Concepts and new things they “need to know” (and must learn)</td>
<td>Engineering Solution to Problem</td>
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<tr>
<td></td>
<td>Basic Engineering Courses</td>
<td>New skills</td>
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<td>Courses from Major</td>
<td>Assumptions, standards…</td>
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<td>Suggestions, corrections, and other external input</td>
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<td>BME, MSE, and ME require design and build.</td>
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# ME/MSE 498 – Preliminaries

<table>
<thead>
<tr>
<th>Meeting</th>
<th>Topic</th>
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<tbody>
<tr>
<td>1</td>
<td>Senior Design Process and Goals</td>
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<tr>
<td>2</td>
<td>The Design Process</td>
</tr>
<tr>
<td>3</td>
<td>Technical Writing and Presentations (Review)</td>
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<tr>
<td>4</td>
<td>Team Building and Evaluation Process</td>
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<td>Solid Modeling &amp; design concepts</td>
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<td>5</td>
<td>Mini-Project 1 Presentations</td>
</tr>
<tr>
<td>6-10</td>
<td>Pro/E</td>
</tr>
<tr>
<td>11</td>
<td>Mini-project 2 Team meeting in class, work allocation and team coordination</td>
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<tr>
<td>12-13</td>
<td>Materials Selection</td>
</tr>
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<td>14</td>
<td>Finite Element Analysis</td>
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<tr>
<td>15</td>
<td>Professional Ethics (with Assignment)</td>
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<tr>
<td>16-17</td>
<td>Mini-Project 2 work day and question session</td>
</tr>
<tr>
<td>18-19</td>
<td>Mini-Project 2 Presentations</td>
</tr>
<tr>
<td>21</td>
<td>Intellectual property; patents, copyrights, trademarks, Dr. Fitzmaurice, UABRF</td>
</tr>
<tr>
<td>22</td>
<td>Business Engineering Interface (Dr. Eric Jack)</td>
</tr>
</tbody>
</table>
# ME/MSE 498/499 – Final Design

## MSE 498:

<table>
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<tr>
<th>Meeting</th>
<th>Topic</th>
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<tbody>
<tr>
<td>3</td>
<td>Outline of MSE/ME/BME 499 Projects</td>
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<tr>
<td>20</td>
<td>MSE/ME 499 Team meeting in class, work allocation and team coordination Team expectation sheet due</td>
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<tr>
<td>23-25</td>
<td>Roundtable discussion of ME/MSE 499 projects</td>
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<tr>
<td>26-27</td>
<td>ME/MSE 499 Preliminary Design Review with Drawings and Calculations; Progress Presentations and Report Due</td>
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## MSE 499:

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<th>Meeting</th>
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<tr>
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<td>Design Review Meetings with Faculty</td>
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<td>4</td>
<td>Design Review Meetings with Faculty</td>
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<tr>
<td>8</td>
<td>Design Review Meetings with Faculty</td>
</tr>
<tr>
<td>12</td>
<td>Design Review Meetings with Faculty</td>
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<tr>
<td>Final Examination</td>
<td>Presentation to Faculty, students, advisory boards</td>
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Reports, Expectations, and Assessment

(Most Learned by Disappointment)
Reports and Expectations

- Must fight senioritis and group-think
- Draft reports are a necessity
- Multiple faculty participating makes criticism easier and reviews more uniform
- Professionalism is part of it
- Must ask for what you want:
  - Report format
  - Discipline-specific issues
Example - Report

1. Title Page
2. Executive Summary
3. Introduction
   - Why is your project of interest? What has been done before? What are you doing?
4. Problem Statement
5. Design Constraints
   - This section must include applicable codes and standards.
6. Brainstorming and Design Alternatives
   - Include sketches, an evaluation matrix, and rudimentary cost analysis for the ideas which were considered during the brainstorming phase.
7. Engineering Design
   - Minimally, include engineering drawings, calculations (and their underlying assumptions), safety factors, the history of the design progression, and compliance with codes and standards.
   - Planning is a critical step in a design project. Your report should also include a detailed cost estimate and a GANTT chart with tasks and responsible parties.
   - This section should be based upon your design prior to construction.
12. Broader Impacts

- Senior design projects often address educational aspects well beyond traditional engineering skills. Examples include:
  - Professional and ethical responsibility. [Engineering Criterion 3(f)]
  - Impact of engineering solutions in a global, economic, environmental, and societal context. [Engineering Criterion 3(h)]
  - Contemporary issues [Engineering Criterion 3(j)]
Discipline Specific Issues

MSE students on teams are given a clear charge:

- You will have a major role in materials selection, which entails identifying the materials class (metal, polymer, ceramic, composite), specific material, and processing method (including heat treatment). You are expected to apply criteria such as cost, weight, design life, stress, availability, environment, and codes in this decision-making. You will often rely on other engineers for load data, weight limits, and other factors that influence the selection process.

- You will typically be the resource for materials data such as density, strength, corrosion resistance, cost, and availability.

- You will have a major role in materials processing, which includes fabricating the final design.

- You are the resource for how processing, properties, and structure affect performance.

- You are responsible for proper materials specifications on drawings and documentation.

- You will often have a major role in testing and characterization of test samples, as-received materials, and the final product.
Assessment

• Engineering accreditation is driven by direct assessment of workproduct using rubrics.

• Senior Design reports and presentations are a perfect opportunity for summative assessment.
  – Reports
  – Tapes of presentations
Examples of Projects
Stair Trainer at Hand in Hand

- Children with “mild” cerebral palsy need training for stair climbing
- Light-weight composite material
- Modular design for storage
- Compliant with playground regulations
- MSE students
- Eberhardt, Vaidya, Janowski, Andrews oversight
- Funded by Eberhardt’s NSF grant
Personal Lift Pedestal (PLP) for Lower Limb Amputees

- Allows amputee to reach standing heights
- Need to add a mobility unit
- Eberhardt oversight
- Funded by Eberhardt’s NSF grant
- BME students
NASA Moonbuggy

- Must fold to a given dimension
- Self-powered
- Funded by ME Department
- ME and MSE students
- Directed by Oliver
Children’s Stander for UCP

- Allows child to easily transition from vertical to horizontal position
- Funded by Eberhardt’s NSF grant
- ME students
A Few Others

- **Formula SAE Car (Twice)**
  - Primary mentor Oliver
  - Andrews, Vaidya, Janowski some help
  - ME and MSE students
  - Funded by ME, MSE, EGR

- **Art/Engineering (Twice)**
  - Art Mentor Kluge
  - EGR Mentor Janowski
  - Art and MSE students

- **Portable Composite Ramp**
  - Mentored by Vaidya, Andrews, Janowski
  - MSE Students
  - Funded by MSE
Role of Faculty
Faculty Roles

• Must have a faculty member or other “adult” overseeing the project.
• Faculty must:
  – Watch schedules
  – Referee teams
  – Critically review progress and make suggestions
  – “Be a boss” and a guide – not a group member
  – Facilitate things with purchasing, accounting…
  – Enforce standards and expectations
• Multiple faculty should be part of reviews, final presentations, and reports

Time commitment can be huge!
Lessons Learned
Team dynamics are tricky

- Student schedules
- Personalities
- Pre-existing relationships
- Low contributors
- Different standards and expectations
- Potential for multiple bosses
Partners across departments are tricky

- Student and faculty cultures
- Scheduling
  - Credit hours
  - Times and semesters
- Communications
- Facilities and expenses

I wish EGR all had the same credit hours over the same semesters!
Some projects do not fit well. Reasons:

- Teams must be too large and not all seniors
- Competition schedules or other deadlines
- Lack design or significant challenge criteria
- Budget excessive
- Cannot “fail”
I already mentioned:

- Report formatting and expectations
- Discipline-specific requirements
- Scheduling and organization must be firm and documented
- It is hard to visualize all of the challenges (or lack of challenges) in an open-ended problem
Summary

- Capstone courses have to be examined in light of their curricula and its goals.
- They can be a wonderful, albeit time intensive, experience for students and faculty.
- They evolve and improve.

Any other questions?