The 2015 Capstone Design Decennial Survey

Current Practices and Trends over Time

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Motivation

• Information about capstone design courses
  • Informal benchmarking
  • Targeted surveys (assessment, discipline-specific)

• What are current practices?

• How are capstone courses evolving?

Understand, improve, and assess capstone design courses
2015 Survey Methods

• Survey Development
  • Combo of 1994 and 2005, plus new ones
  • SurveyMonkey: 65 questions, 11 sections

• Dissemination/Collection
  • Contact database (ABET programs)
  • Email: department chairs, DEED newsletter, CDC mailing list
  • Responses: 522 respondents
    → 256 institutions
    → 464 departments/programs
ABET Accreditation List
• 2386 programs
• 470 institutions

Survey Respondents
• 464 programs
• 256 institutions

Capstone Conf. Attendees
(as of 5/31/2016, #s increased later)
• 119 programs
• 77 institutions
Results Overview

- 2015 Results
- Comparisons
  - Disciplinary
  - Longitudinal (1994, 2005)

Papers: CDC 2016, ASEE 2016
Online: www.capstoneconf.org
        www.cdhub2.org
Most responses from MAE, then EE/CS and CEE → similar for all

“Other” in 2015:
- Specific disciplines - Biomed (36), Mat’ls, Ag, General, etc.
- Responses that cover 2+ disciplines

Overlap = 25-28% dept., 68% inst’n (2005-15)
38 resp. in all 3 surveys
Capstone Course Age

- Wide range of ages: some just started, others 50+ years old
- 1/3 of respondent capstone courses are 25+ years old
- Oldest responding course is 126 years; 5 are 100+ years

n=460
• Biomedical separate from Other

• Most disciplines are roughly normal distribution

• More biomedical capstones are newer

• More chemical capstones are older
Course Information
Structure and Sequence

- Majority run class and project in parallel; even more so 2015
- No 2015 respondent has “Class Only” (no project)
- “Other” responses: mostly combo of options at different times, or variable
Capstone Course Duration

- More than 50% have 2 semester capstone; big jump from prev. surveys
- Drop in 1 semester and 1 quarter duration
- “Other” mostly reflect longer timeframes: 2-3 trimesters, 4 quarters, 3-4 semesters
Disciplines Involved in Capstone

- **Mechanical** (36%)
- **Biomedical** (20%)
- **Chemical** (11%)
- **Civil** (32%)
- **Electrical** (2%)
- **Computer**
- **Industrial/Systems**
- **Environmental**
- **Aero/Astro**
- **Nuclear**
- **Materials**
- **Biological**
- **Architectural**
- **General**

Text size represents frequency of response. (Colors are not significant.)

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Disciplines Involved in Capstone

- Mechanical: 36%
- Electrical: 32%
- Chemical: 20%
- Civil: 11%
- Biomedical: 4%
- Computer: 4%
- Industrial Systems: 12%
- Environmental: 12%
- Other: 1%

Image for non-engineering disciplines enlarged for improved readability.

n=500
Design Prereqs for Capstone

- Courses: dep’t electives, design sequence
- Topics: machine design, CAD, software design, design theory, etc.
- Year-based: freshman design, junior design
- Criteria: # of credits, senior standing

- Specific courses
- Specific engineering topics
- No prerequisites
- Specific year-based courses
- Criteria (level, credits)
- Other topics
- Most/all courses
- Varies
- General yes

(n=312 respondents)
• All 3 surveys: “mark topics covered” from pre-set list, plus write-in option
• Fairly consistent top five topics across all → emphasis on professional skills

• 2015: “where covered”: individual assignment, lecture, team project reqs. → similar themes
# Topics Covered in Capstone: Top 5

## 1994
- Oral communication
- Concept generation
- Teamwork
- Planning/scheduling
- Engineering ethics

## 2005
- Written communication
- Oral communication
- Engineering ethics
- Planning/scheduling
- Decision making

## 2015
- Written communication
- Planning/scheduling
- Oral communication
- Concept gen./selection
- Team building/teamwork

<table>
<thead>
<tr>
<th>2015 Data</th>
<th>Individual Assignment</th>
<th>Written communication</th>
<th>Engineering ethics</th>
<th>Oral communication</th>
<th>Planning/scheduling</th>
<th>Analysis tools</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lecture</strong></td>
<td></td>
<td>Engineering ethics</td>
<td>Planning/scheduling</td>
<td>Concept gen./selection</td>
<td>Standards and regulations</td>
<td>Decision making</td>
</tr>
<tr>
<td><strong>Team Project</strong></td>
<td></td>
<td>Written communication</td>
<td>Oral communication</td>
<td>Planning/scheduling</td>
<td>Analysis tools</td>
<td>Team building/teamwork</td>
</tr>
</tbody>
</table>

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Q: How do you balance product versus process in your capstone design projects?

- "Product is key!"
- "We focus most on the product and very little on processes."
- "The final product is the result of the process so they have to balance."
- "Process wins out, but product usually follows for a good process."
- "We typically don't build the real products, as the system costs millions to construct. Hence, we focus on the design process."

(n=208 respondents with quantifiable comments)
Contributors to Capstone Grading

Course instructors and project coaches have most input on grades.

- Course instructors
- Project advisors/coaches
- Industry liaisons
- Other department faculty
- Students
- Dept. advisory board
- Nat'l competition judges

Percent of Respondents (n=450 to 467)
Evaluation of Deliverables

- Final report, pres’n, and product have biggest role in eval.
- Process, interim work, and design reviews also important
- Peer feedback has at least minor role for 80% of resp.
Faculty and Students
90%: capstone = “normal teaching activity” for T&P
# of Students per Capstone Cycle

- Student numbers are increasing in capstone
- Student/faculty ratios:

  - 1-10
  - 11-20
  - 21-40
  - 41-60
  - 61+
  - <1

Max = 170!

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Expected Student Hours/Week

- Median bracket increased over time:
  - 2005: 7-9 hr/wk
  - 2015: 10-12 hr/wk

- Comments:
  - Expectation varies at different times (e.g., fall/spring)
  - “Expectation = as long as it takes”
Ensuring Student Work Time

Arranging team work time is entirely the students' responsibility

Almost all team work on project happens during lab section scheduled as part of course

Part/all course time set is aside for team work on project; students are responsible for finding other meeting times

Other (please specify)

- 2015: more than 50% have mix of in-class work time and student-arranged time
- “Other”: many noted weekly meetings with faculty coach
Projects and Teams
### Capstone Project Sources

- **Most common:** industry/gov’t, followed by faculty research
- **Increase in entrepreneurial projects, service learning (new)**
- **“Other”: clinicians, instructor ideas**

#### Project Sources Comparison

<table>
<thead>
<tr>
<th>Source</th>
<th>2005 (n=394)</th>
<th>2015 (n=460)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faculty research</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry/government</td>
<td></td>
<td></td>
</tr>
<tr>
<td>External competitions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service learning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student/entrepreneurial</td>
<td></td>
<td></td>
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<tr>
<td>Textbooks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Data

- **1994 Data (n=341)**
  - Industry: 59%
  - Internally: 58%
  - Other: 15%

- **2005 (n=394)**
- **2015 (n=460)**

#### Increase in

- Student/entrepreneurial projects
- Service learning (new)

#### Other:

- Clinicians
- Instructor ideas

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Project Sources by Discipline

- Faculty research: BME, EE/CS, MAE
- Competitions: ChE, MAE
- Entrepreneurial: EE/CS, MAE
- IE: almost all industry/gov
- CEE: industry and service learning
Finding Capstone Projects

- External Contacts
- Internal Sources
- Marketing
- Prefab/ready to go
- Current interest
- Magnet
- Development/grants
- All/Nothing
- Events-based

Percent of Respondents (n=321)

- Global trends
- Topical areas
- Student ideas
- Faculty research
- Campus projects
- Competitions
- Repeat projects
- Textbooks
- Clients come to us
- Reputation
- Solicitation
- Networking
- Advertising
- LinkedIn

Local industries
Alumni
Advisory board
Previous sponsors
Personal contacts

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# of Projects per Capstone Course

- Data from all years have a range of average # of projects per course cycle (1-15+)
- Overall increase in number of projects: 25% of 2015 respondents have >15 projects
- Max = 87 for 2015
# of Projects by Discipline

- **Spread across disciplines for # of projects**
- **>15 projects:** BME and MAE
- **1 project:** CEE
# of Students per Capstone Team

- Categories represent average number of students/team
- #s in brackets show [min,max] reported within category
- 75%+ of respondents have 3-5 students/team

- 1 student [1,4]
- 2 students [1,15]
- 3 students [1,12]
- 4 students [1,16]
- 6-7 students [1,25]
- 8-10 students [4,20]
- >10 students [6,100]

n=447
Students/Team by Discipline

- 4 person teams most common for most disciplines, (3 for BME, IE)
- Larger team sizes small minority for all disciplines

Percent of Respondents

- Biomedical (n=34)
- Chemical (n=31)
- Civil (n=70)
- Electrical (n=75)
- Mechanical (n=105)
- Industrial (n=21)
- Other (n=111)
Assigning Students to Teams

- Student choice most common option for team assignment
- Instructor choice and student skills also common
- “Other” = CATME, GPA, schedules, random

Random assignment
Personality test (MBTI, etc.)
Student skills for project
Student choice
Instructor choice
Project advisor choice
Other

Percent of Respondents (n=458)
Funding
Types of Capstone Expenses

- Project supplies, hardware, and software most common expenses
- “Other” = external fabrication/analysis, personnel/summer salary, no expenses
Breakeven Costs per Project

- Each data point represents one respondent (n=325)
- Max breakeven = $50k, but majority are much less
- 300 are < $5k
- 200 are < $1k
- 50 have no costs
Breakeven Costs by Discipline

- All disciplines have majority of breakeven costs less than $1k
- Most expensive are MAE and some Other (mining, MSE, general eng.)
Capstone Project Funding Sources

- Institution and sponsors as primary funding sources
- Students less likely to fund projects
- “Other” = individuals, no funding, variable

<table>
<thead>
<tr>
<th>Source</th>
<th>1994 Data (n=354)</th>
<th>2005 Data (n=341)</th>
<th>2015 Data (n=451)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sponsor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Institution</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Percent of Respondents

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Sponsors
External Sponsor Funding

<table>
<thead>
<tr>
<th>Variable</th>
<th>1994 Data (n=202)</th>
<th>2005 Data (n=254)</th>
<th>2015 Data (n=266)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; $5000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$1000-5000</td>
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<td>$500-1000</td>
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<tr>
<td>&lt; $500</td>
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<tr>
<td>Zero</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Variable</td>
<td></td>
<td></td>
<td>(2005 choice only)</td>
</tr>
</tbody>
</table>

2015 = average $ 

Min = $0 for all brackets 
Max = $0-250k, median max = $5k 

n=266
Most funding: IE, MAE, Other

Least funding: ChE, CEE

"[Funds are] not an issue. Chemical engineering capstone process design is entirely virtual."
Intellectual Property Ownership

- IP ownership increasing; sponsor most common owner, but IP is often divided
- 66% of respondents: division varies by project and/or is governed by processes or criteria (negotiation, individual contribution, inst’n policy or state law, etc.)
- Students sometimes granted royalties, not IP ownership
Capstone Sponsor Location

- **International**: choice only in 2015
- Locations fairly consistent across discipline
- Student trips to sponsor:
  - Range = 0-100
  - Median = 2

### Percent of Respondents

<table>
<thead>
<tr>
<th>Year</th>
<th>Locally (&lt;20 miles)</th>
<th>Regionally (20-100 miles)</th>
<th>Nationally (&gt;100 miles)</th>
<th>Internationally</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2015</strong> (n=293)</td>
<td>71</td>
<td>65</td>
<td>37</td>
<td>13</td>
</tr>
<tr>
<td><strong>2005</strong> (n=235)</td>
<td>77</td>
<td>70</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td><strong>1994</strong> (n=202)</td>
<td>83</td>
<td>55</td>
<td>27</td>
<td></td>
</tr>
</tbody>
</table>

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Contact with Capstone Sponsor

- Weekly contact with sponsors still most common
- Biweekly option added in 2015 survey: 19%
- “Other” = most noted that contact varies depending on project, sponsor, and team

### Contact Frequency

- **Weekly**
  - 1994 Data (n=202)
  - 2005 Data (n=242)
  - 2015 Data (n=292)

- **Biweekly**
  - (2015 choice only)

- **Monthly**

- **Beginning and Final**

- **Other**

### Data Analysis

- Weekly contact remains the most common method of communication.
- The addition of a biweekly option in 2015 increased its usage to 19%.
- Respondents noted that the frequency of contact varies depending on the specific project, sponsor, and team dynamics.

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Repeat sponsorship is common for at least some, if not all, sponsors.

Comments noted variability depending on year and sponsor, some sponsors “take time off” and then return.

n=288
Summary

Data Sources

- 2015 Survey: 522
- 2005 Survey: 444
- 1994 Survey: 360

Survey Results

- Respondents
- Course Information
- Pedagogy
- Faculty and Students
- Projects and Teams
- Funding
- Sponsors

many patterns, much variety
What Do You Like Most?

Student Success & Accomplishment
“Seeing the students succeed and overcome their struggles during the semester.”

Student Growth & Confidence
“Seeing the students mature in confidence.”

Application of Previous Learning/Skills
“It is very enjoyable to work with students as they discover the usefulness and application of their education.”

Student Joy & Excitement
“The positive energy in the class is contagious.”
What Do You Like Most?

Percent of Respondents (n=361)

- **Personal Success**
- **Interaction**
- **Professional Development**
- **Variety**
- **Process**
- **Advising**
- **Real World**
- **Creativity**
- **Project Success**
- **Uniqueness**
- **Everything/Nothing**

**With Students**
"Interaction with talented, motivated students."

**With Industry**
"Interacting with the project sponsors."
What Do You Like Most?

- Personal Success
- Interaction
- Professional Development
- Variety
- Process
- Advising
- Real World
- Creativity
- Project Success
- Uniqueness
- Everything/Nothing

“Seeing the team members evolve from students to novice engineers in their final year of coursework.”

“New challenges for new projects with fresh ideas from new sets of students.”

“The fact that the design process is very complex and requires engaging both the right as well as the left side of the brain.”

“Not a standard lecture course.”
Future Work

Decennial Surveys

1994  2005  2015  2025  2035

Global Expansion  Connection to Outcomes
Acknowledgements:
Sophia Poulos, Laura Rosenbauer, Natasha Culbreth, Iris Umaña, Jay Pembridge, Rick Berkey, Jay Goldberg, Marie Paretti
Additional Graphs
Topics as Part of Team Project Reqs.

- Written communication (n=472)
- Project planning and scheduling (n=468)
- Team building/teamwork (n=463)
- Concept generation (n=453)
- Creativity/problem solving (n=462)
- Prototyping and testing (n=445)
- CAD design and layout (n=440)
- Optimization (n=430)
- Sketching (n=422)
- Intellectual property/patents (n=440)
# of Credits for Capstone

Credits for capstone design course as a percentage of credits required for graduation

- 6.0%+<br>- 5.0-5.9%<br>- 4.0-4.9%<br>- 3.0-3.9%<br>- 2.0-2.9%<br>- <2.0%

n=462
Instruction for Students from Different Disciplines

- One class section with the same instruction offered to all students (n=207)
- Separate class sections and instructions for students from different departments
- Students receive both common and department-specific class instruction
- No formal class instruction
- Other
How Are Graduate Students Involved?

- Supervise capstone projects related to their graduate research
- Advise undergraduates on technical knowledge
- Assist undergraduates with experimental work
- Assist undergraduates with prototyping
- Not involved
- Not applicable - no graduate students
- Other

Percent of Respondents (n = 474)
Number of Students in Capstone Course by Discipline

- Biomedical (n=33)
- Chemical (n=28)
- Civil (n=74)
- Electrical (n=77)
- Industrial (n=22)
- Mechanical (n=106)
- Other (n=109)

Percent of Respondents:
- 10 or fewer
- 11-20
- 21-30
- 31-40
- 41-50
- 51-70
- 71-100
- 101-200
- More than 200
Student-Faculty Ratio in Capstone Course by Discipline

(Based on # of faculty who receive teaching credit for capstone)
Total Student Time Spent per Project

- <200 hrs
- 201-400 hrs
- 401-600 hrs
- 601-800 hrs
- 801-1000 hrs
- 1001-1200 hrs
- 1201-1400 hrs
- 1401-1600 hrs
- 1601-1800 hrs
- 1801-2000 hrs
- >2000 hrs
- Don't know

n=454
Forms of Capstone Sponsor Funding

- Grants
- Gifts
- Reimbursement
- Other

Percent of Respondents

- 2005 Data (n=236)
- 2015 Data (n=274)