Session 2366

The State of Mechanical Engineering Design Education: Results of a Web-based Survey

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Abstract

A web-based survey of mechanical engineering programs was conducted, with the assistance of ASME, to assess the manner in which design is spread across the curriculum. Forty-six schools responded to the survey, which consisted of 18 questions per design course identified by the school. Specific emphases were given to defining: (1) the nature of the freshman design experience, (2) the nature of the senior capstone experience, (3) the level of integration of computer-aided design software in courses and (4) the degree to which hands-on projects are employed.

Introduction

The current state of mechanical engineering design education is the product of a number of factors. ABET requirements, arising in part from perceptions of the needs of industry, have certainly played a role. Widespread changes in higher education (e.g. economic forces, demographics, new computing tools) have also affected how design education is delivered. To help quantify discussions concerning adequacy of contemporary design education in light of industry's needs and academia's constraints, we have undertaken this national survey.

A baseline understanding of current curricula can help relieve potential anxiety in mechanical engineering programs during the transition to ABET's EC2000 evaluation criteria with regard to design content. Under the old accreditation procedures, universities were provided quantitative guidelines for adequate inclusion of design topics in the curriculum. While that policy may have resulted in a degree of uniformity and may have inhibited innovation, it did provide a measure of security. Now that ABET has adopted a more flexible approach in permitting programs to set the level of design concentration in the curriculum to correspond with published objectives and outcomes, there is a need to understand what the norms are across the country as schools begin to implement curricular innovations.

Other surveys have largely focused on prioritization of potential topics related to design such as teamwork, creativity, ability to read drawings, and knowledge of tolerancing. For example, in a recent study Eggert[1] queried both academia and industry using parallel web-based surveys to contrast the list of design topics currently being taught with the needs of industry.

The purpose of the questionnaire described in this paper was to determine the curricular structure and components employed by ABET accredited M.E. departments to teach engineering design. It was intended to elucidate both how design is spread across the curriculum as well as the nature of those experiences, with regard to industrial sponsorship, use of hands-on projects, and integration of CAD. Discussion of survey content and results will culminate with construction of a "typical" design program.

Design and Distribution of the Web-based Survey

The questions in the survey were designed to yield as much information as possible while still encouraging participation. For this reason, the number of questions was limited to 18 per course self-identified by the department as being a design course. Answers were kept brief, requiring either a numeric value, or response to a yes/no or multiple choice question. Questions were posed in a random order and formulated so as not to favor a particular response. Questions were also designed such that cross-referencing of responses to different questions would yield additional information.

The survey questions are listed in Table 1. Possible responses to multiple choice questions are shown within parentheses. The format of the actual screen layout is illustrated in Figure 1 for the first 3 questions. As shown, each question is posed once, with responses for 5 design courses arranged columnwise beneath the question. Respondents were asked to log in a second time to report any design courses in excess of 5. The fact that only 5 columns were provided for responses may have biased the number of courses evaluated.

The questions were distributed and filled out on-line for convenience. The web link was sent by ASME to all heads of ABET accredited mechanical engineering programs. Identities of participating schools were kept confidential.

Survey Respondents

Of 203 schools receiving the web link, 46 responded, including one Canadian university. The mix involved both private and public institutions, with the size of faculties ranging from 7 to more than 50 members. The backgrounds of faculty teaching design courses was quite diverse (see Table 2). Among the participating schools, 74% were on a semester system, 24% on a quarter system, and 2% on a trimester system.

A total of 187 design courses were reported, with 91% of those courses being classified as "required". This yields an average of 4.1 design courses per program. Variations in the reported number of design courses per program are shown in Figure 2, with the qualifier that the indicated skewing may be an artifact of the screen layout.

Results

In this section, results of the survey will be presented without comment. Issues of general interest are used to organize the results.

Design across the curriculum

A year-by-year breakdown of results provided some insights. The distribution of reported design courses across the four years is presented in Table 3. The first introduction of CAD and the first experience at building a working device are indicated in Tables 4 and 5, respectively. Summarizing these and other results:

- 86% of all reported design courses was offered during the junior and senior years.
- 75% of all reported design courses had students working in teams.
- 74% of reporting M.E. programs had introduced CAD by the end of the junior year.
- 54% of reporting M.E. programs had required the building of a working device by the end of the junior year. 11% of the schools reported never requiring the students to build a working device.

The capstone design experience

43 (93%) of the programs reported having "capstone" design courses. All were in the senior year except for one school's capstone course in the final semester of the junior year. Of these 43 programs:

- 100% report having students work in teams during their capstone experience. Typical team sizes range from 2 to 5 students. 14% reported team sizes of more than 6 students.
- 81% have students working directly with engineers from industry.
- 65% report receiving "significant" funding from industry for student projects.
- 91% require the students to build a working device. Of these programs, 56% have the students performing the majority of the hands-on fabrication, 32% have an even split between student fabrication and technicians/machinists, and 12% have technicians/machinists performing the majority of the hands-on fabrication.
- 51% involve student competitions.
- 88% require the use of CAD.
- 86% require design and realization of both mechanical and thermal/fluid systems.

The freshman design experience

13 (28%) of the programs reported having design courses in the freshman year. 11 of the 13 programs offered the course in the first term while one school reported a two semester sequence. Of these 13 programs:

- 85% introduce CAD in the freshman year.
- 54% involve student competitions.
- 46% require students to build a working device.

- None reported student interaction with members from industry.
- None reported "significant" external funding from industry.

The "Typical" Design Program

Responses corresponding to mean values (or 50% cumulative frequency) were used to construct a representation of a "typical" design program. Characteristics of this program are as follows:

- There are a total of 4 design courses, all 4 of which would be required.
- First design course occurs in the junior year.
- CAD is introduced in the junior year.
- There are 2 design courses in the junior year, and 2 in the senior year.
- 3 design courses would have students working in teams; one would have students working individually.
- A third of the courses would be taught by someone whose research area is design, a third by someone in solid mechanics or thermal/fluids, and a third by someone in another area.
- Two of the courses would represent a capstone design sequence in the senior year. In these two courses, students would:
  - work in teams of 2 to 5 students each
  - work directly with engineers from industry
  - receive significant funding from industry
  - build a working device with students performing the majority of the hands-on fabrication
  - participate in a design competition
  - design and realize mechanical and thermal/fluid systems

Conclusions

A national online survey of ABET accredited mechanical engineering programs was conducted during the summer of 2001 to determine the nature and frequency of engineering design courses within today's programs. Based on results from the 46 schools that responded, it is clear that design courses, at an average of 4.1 courses per program, now comprise a substantial fraction of courses in the major. A senior capstone design course is now a fixture in almost all programs. Teaming, use of CAD, building of a working device, and significant interactions with industry are standard features in these capstone courses. Realization of both mechanical and thermal/fluid systems is also indicated as per the EC2000 criteria. However it may not be clear from wording of the related question whether both mechanical and thermal/fluid experiences always occur within the same course offering. In addition, 41% of programs are delivering a design course within the first 2 years.

References

1 Eggert, R.J., Boise State University, correspondence containing results of on-line survey, 2002.

Biographical Information

MICHAEL C. LARSON
Michael C. Larson is an Associate Professor in the Mechanical Engineering Department at Tulane University. He earned his PhD from MIT. His efforts in teaching engineering design have been recognized by a Lee H. Johnson Award for Teaching Excellence, a Tulane Excellence in Undergraduate Teaching Award, an SAE Ralph R. Teetor Educational Award, and twice being selected by students as his department's "professor of the year."

WILLIAM D. KEAT
William D. Keat is an Associate Professor of Mechanical Engineering at Union College. Professor Keat earned BS and MS degrees in mechanical engineering from Worcester Polytechnic Institute and a PhD in mechanical engineering from the Massachusetts Institute of Technology. He has taught numerous courses in design from the freshman to the graduate level and conducts research in the area of computational fracture mechanics.

Q1. What is the course name?
Q2. Is this course required for all bachelor's degree candidates?
Q3. Does the course require the design and realization of mechanical or thermal/fluid systems?
Q4. Do you consider this a "capstone" course?
Q5. How many credit hours is this course?
Q6. Do industry members work directly with students?
Q7. Do you receive significant external funding form industry for student projects?
Q8. What is this course's approximate enrollment?
Q9. Does this course involve any competitions between students?
Q10. What is the number of faculty involved in instruction?
Q11. Are students required to build a working device?
Q12. If the answer to the previous question is "yes", who performs the majority of the hands-on fabrication of the projects? (*students, technician/machinists, even split*)
Q13. Does the course require the use of CAD software?
Q14. Do students work in teams or as individuals?
Q15. If the answer to the previous question is "T", what is the typical number of students per team?
Q16. Is your academic calendar organized around a quarter, trimester or semester system? Select year and placement (e.g. "2" will correspond to the second quarter, second trimester or second semester as applicable).
Q17. Which category most accurately describes the research area of the faculty teaching this course? (*design, solid mechanics, thermal/fluids, other*)
Q18. COMMENTS: Please add any further information that you feel will be helpful to us in understanding how this course serves to meet your program objectives. Of particular interest is any feedback you have received about this course and your design education from an accreditation review under the EC2000 guidelines.

Table 1 Survey questions listed verbatim and in the same order as they appeared within the questionnaire.

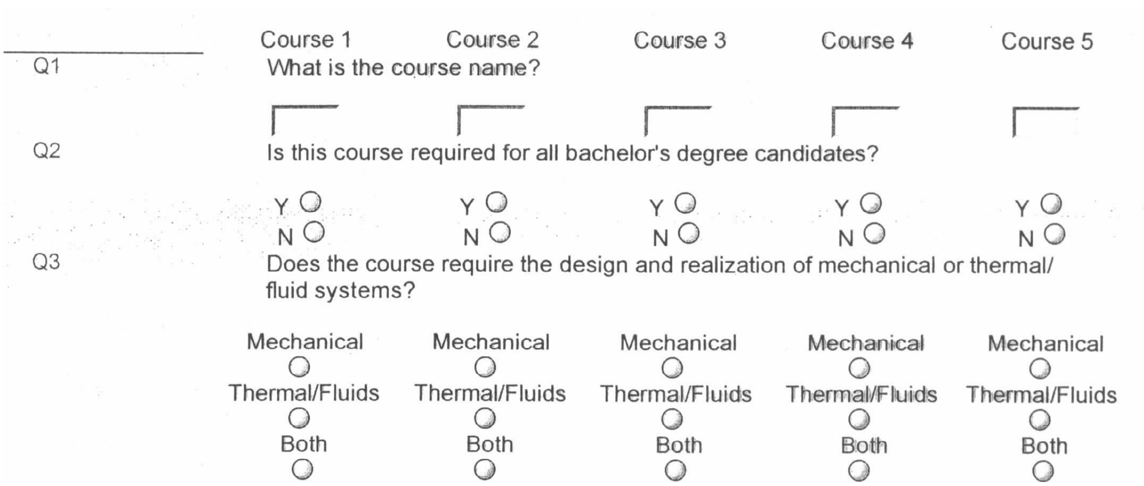

Figure 1 Web site screen layout

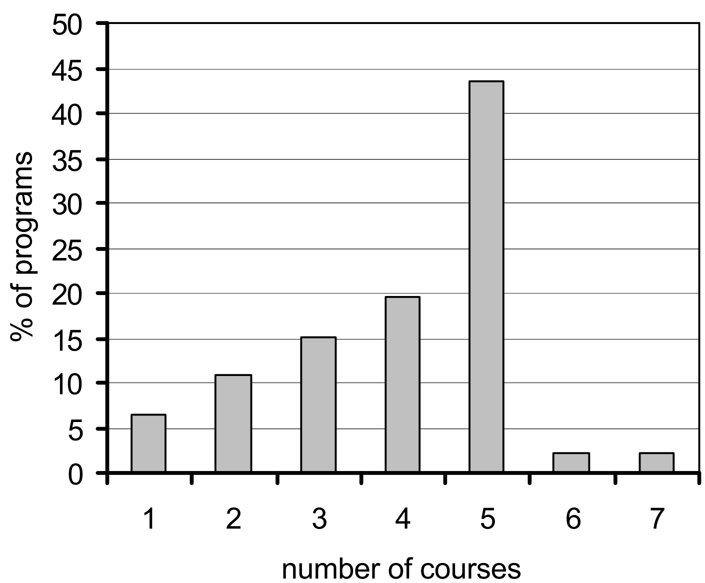

Figure 2 Number of design courses per program

Research area of faculty teaching design courses:

Design	**64**	**34%**
Thermal/fluids	**35**	**19%**
Solid Mechanics	**32**	**17%**
Other	**56**	**30%**

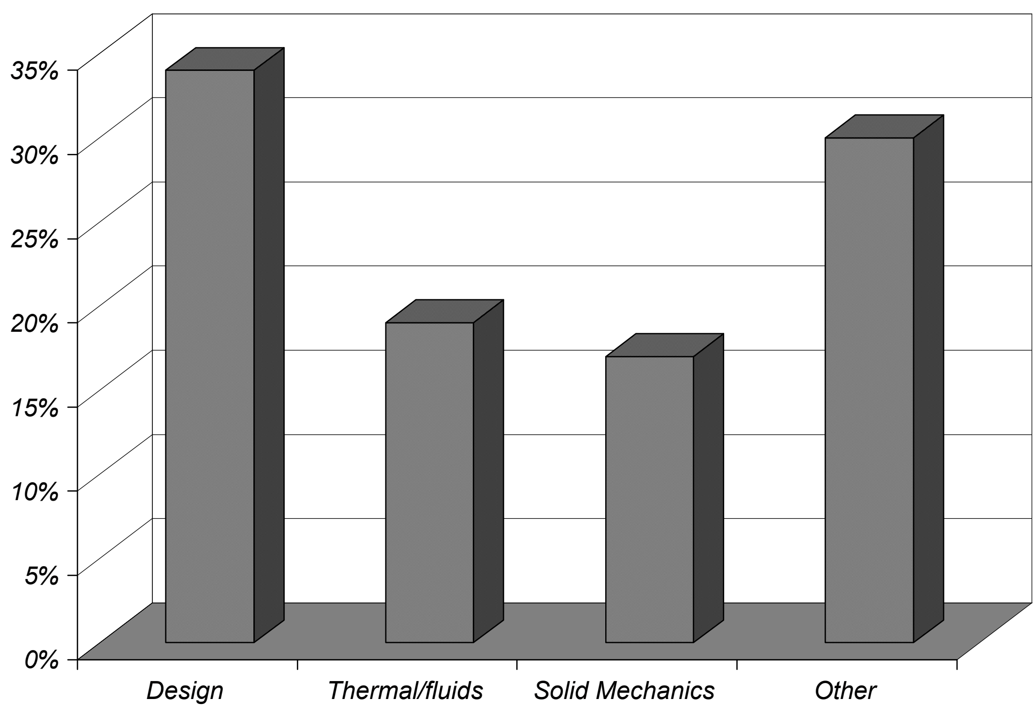

Table 2 Design faculty backgrounds

Total number of design courses, by year:

Freshman Year	**14**	**8%**
Sophomore Year	**12**	**6%**
Junior Year	**61**	**33%**
Senior Year	**100**	**53%**

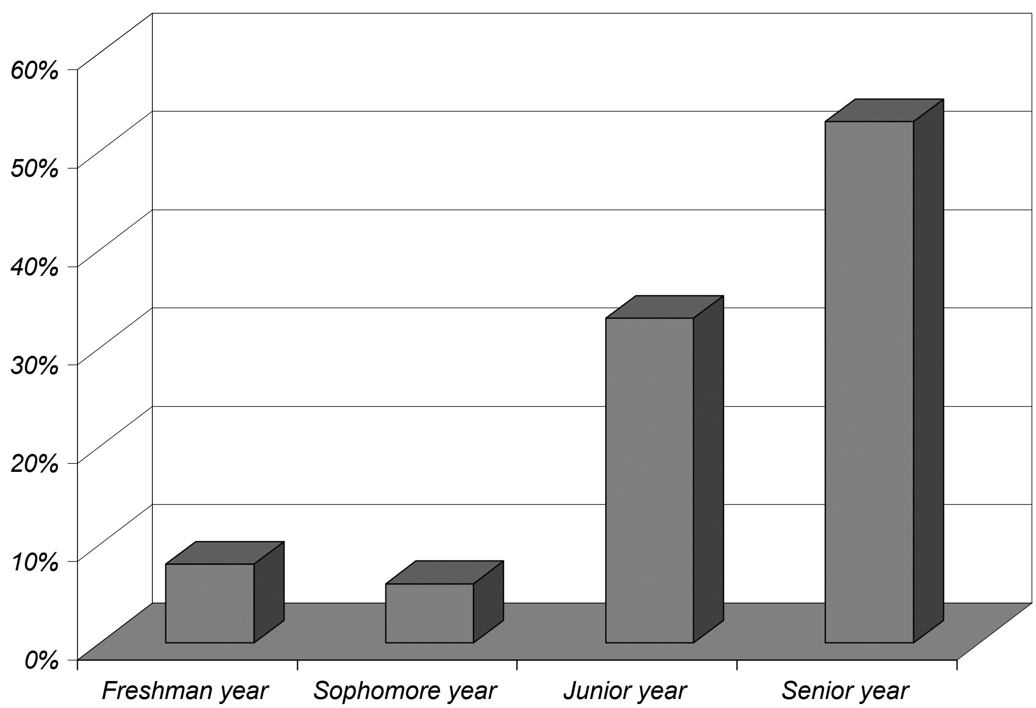

Table 3 Distribution of reported design courses across the 4 years.

Curricular introduction of CAD, by program:

Freshman Year	**10**	**22%**
Sophomore Year	**9**	**19%**
Junior Year	**15**	**33%**
Senior Year	**12**	**26%**

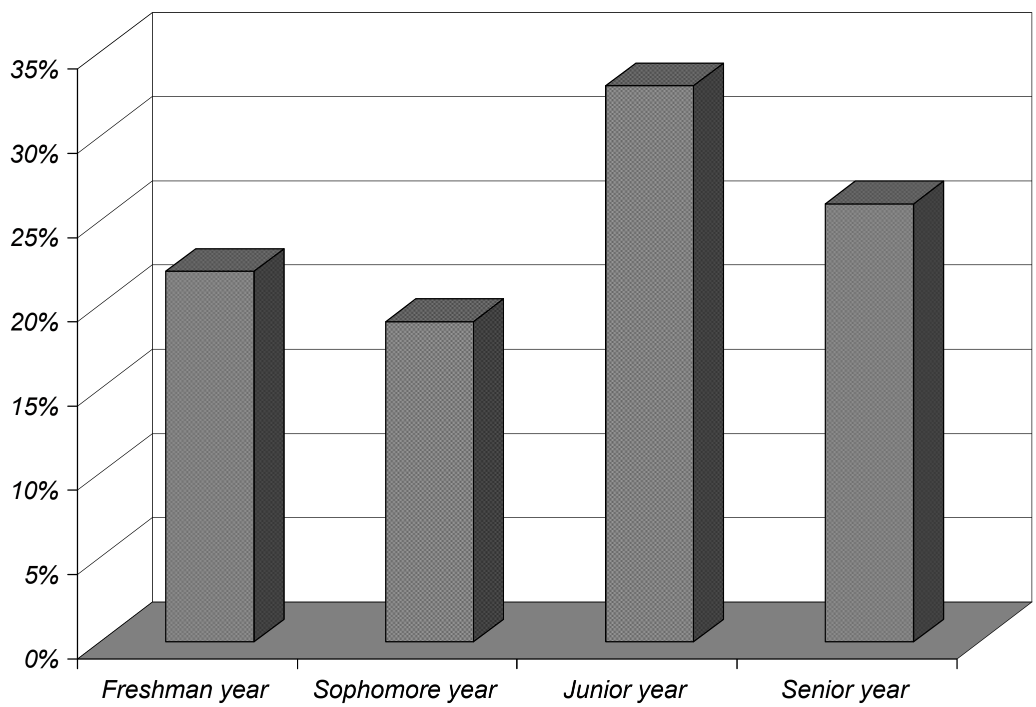

Table 4 First introduction of CAD.

Curricular introduction of building a working device, by program

Freshman Year	**6**	**13%**
Sophomore Year	**9**	**19%**
Junior Year	**10**	**22%**
Senior Year	**16**	**35%**
No building	**5**	**11%**

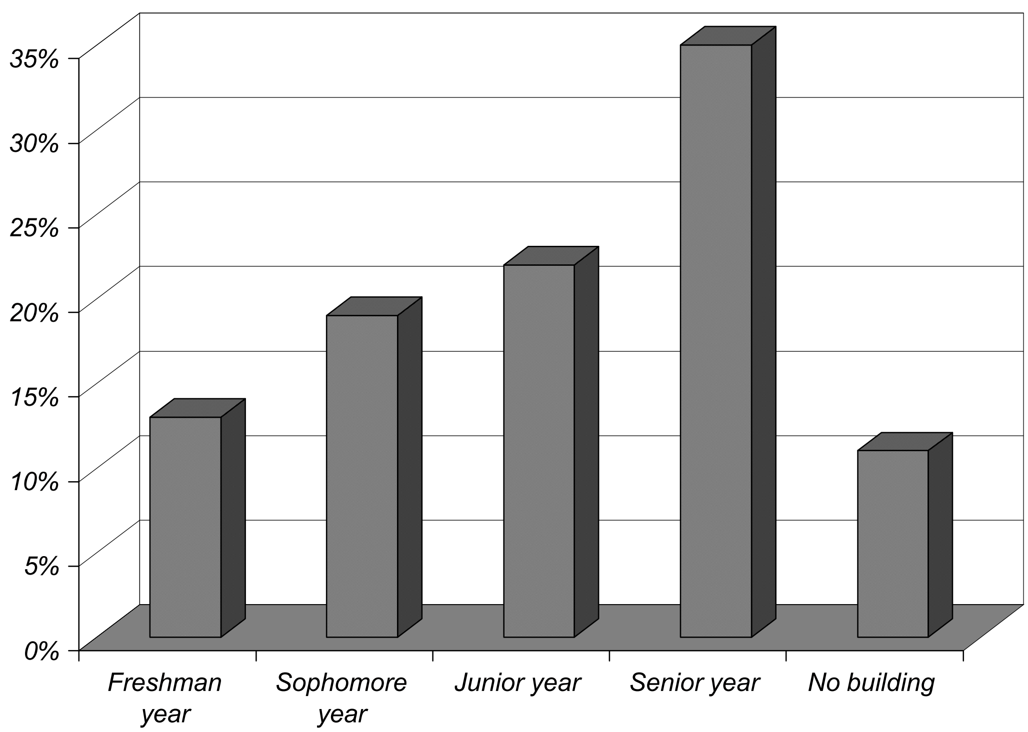

Table 5 First experience at building a working device.