AC 2008-2318: FOCUSED FOLLOW-UP TO 2005 NATIONAL CAPSTONE SURVEY

Susannah Howe, Smith College

Susannah Howe is the Design Clinic Director in the Picker Engineering Program at Smith College. She coordinates and teaches the capstone engineering design course and serves as co-faculty advisor for entrepreneurial activity at Smith. Her interests include innovations in engineering design education, entrepreneurship education across disciplines at the undergraduate level, and durability and structural performance of cementitious and natural building materials.

Focused Follow-Up to 2005 National Capstone Survey

Abstract

This work details a survey of engineering capstone design courses focused on faculty teaching load and capstone funding levels. The survey was distributed to the attendees of the inaugural National Capstone Design Course Conference in June 2007. The survey yielded responses from 59 participants, representing 45 institutions. The results of the survey provide valuable insight into number and duration of design projects, team size, capstone teaching credit, faculty involvement, direct project costs, and external funding levels.

1. Introduction

Capstone design courses offer engineering students a culminating design experience through an applied engineering project. Encouraged in part by ABET support, these courses have become common in engineering departments across the United States. The composition of capstone courses, however, varies widely, as demonstrated by results from national surveys in both 1994 [1] and 2005 [2,3]. Highlights of the 2005 survey results, in comparison with the 1994 predecessors where possible, were presented at the opening keynote address of the inaugural National Capstone Design Course Conference in June 2007.

While both surveys gathered volumes of data about practices in capstone education, specifics of faculty teaching load and range of capstone funding levels for a given program were not captured precisely. In order to address teaching load and funding levels in more detail, a focused follow-up survey was distributed to attendees at the conference. The results and their analysis contribute to an ongoing effort to better understand and, ultimately improve, engineering capstone design education.

2. Methods

The inaugural National Capstone Design Course Conference in June 2007 mentioned above opened with a keynote session focused on capstone design course data from two national surveys. Near the beginning of this presentation, audience members received a two-page paper survey and were encouraged to complete it with information about their own capstone programs. Some respondents submitted their completed surveys at the end of the keynote session but the majority deposited theirs in a collection box at the conference registration table. A few respondents sent their results to the author by email or post following the conference.

Approximately 150 people attended the conference; the exact number of attendees at the keynote session is unknown. From the audience in attendance, the survey yielded responses from 59 faculty, representing 55 distinct departments at 45 institutions. This respondent pool is not a random sample of capstone programs nationally or globally, but rather a self-selected pool from those attending the capstone conference. Note also that the capstone audience represented only a small sample of the total number of ABET-accredited programs nationally (1796 in fall 2006 [4]) the vast majority of which, as previous survey results suggest [1,2,3], likely have capstone courses.

3. Survey Results and Discussion

The results of the follow-up survey are discussed below. The data are organized into four sections: respondent profile, project logistics, faculty credit/involvement, and costs/funding levels. Where possible, comparisons with the 2005 and 1994 predecessor survey results are given.

3A. Respondent Profile

Figure 1 shows the 2007 survey respondents sorted by department, in comparison with the respondents in 1994 and 2005. As in previous papers [2,3], the specific categories were chosen for ease of comparison; departments were grouped as closely as possible. Of note for the 2007 results is the total lack of respondents from chemical engineering. This was countered by a sizable representation in mechanical engineering. The "Other Engineering" category was also well-represented and included such departments as biomedical, materials, and ocean engineering plus general engineering and interdisciplinary departments.

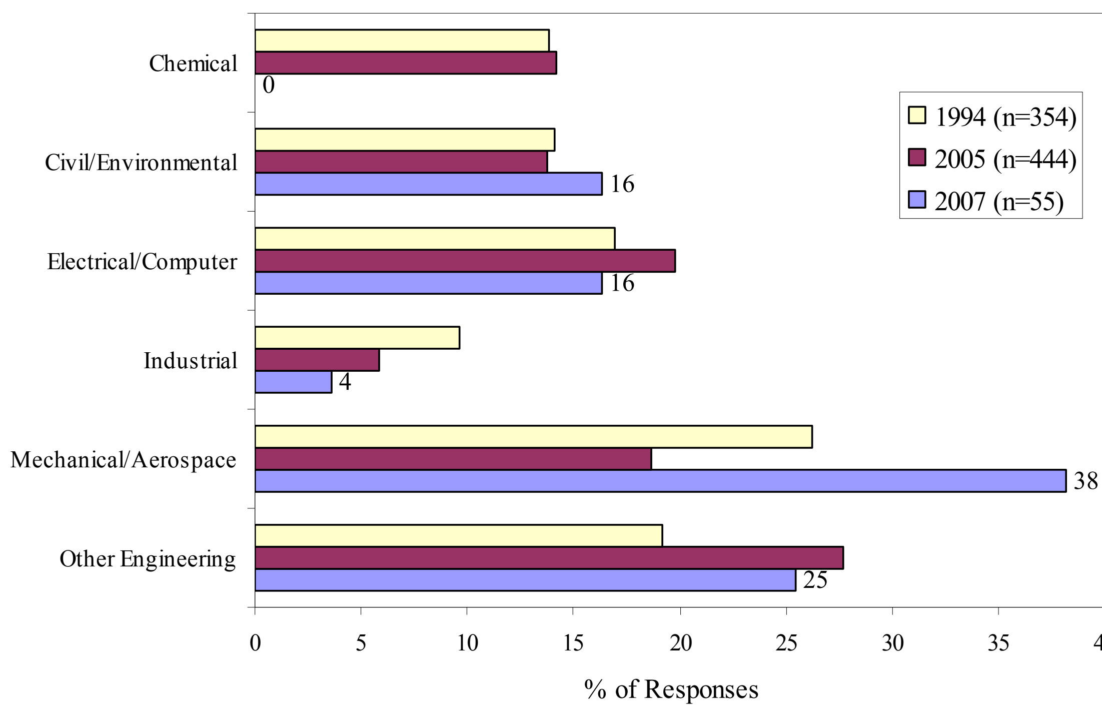

Figure 1 - Percent of Responses by Department

Figure 2 shows the age of the capstone courses for respondents from both 2005 and 2007; note that the age reported is as of the year the survey was completed (i.e., 2005 or 2007). Most notable in this graph is the majority of capstone courses from the 2007 pool that are 16 years or older coupled with the tiny minority of new programs, contrasting with the inverted profile in the 2005 survey. This representation of the older capstone courses (the oldest was 50, and one-sixth reported 35 years or older) suggests that the inaugural capstone conference attracted representatives from more established capstone programs. A further observation supporting this hypothesis is that the conference was divided into three main tracks, only one of which focused on starting a program.

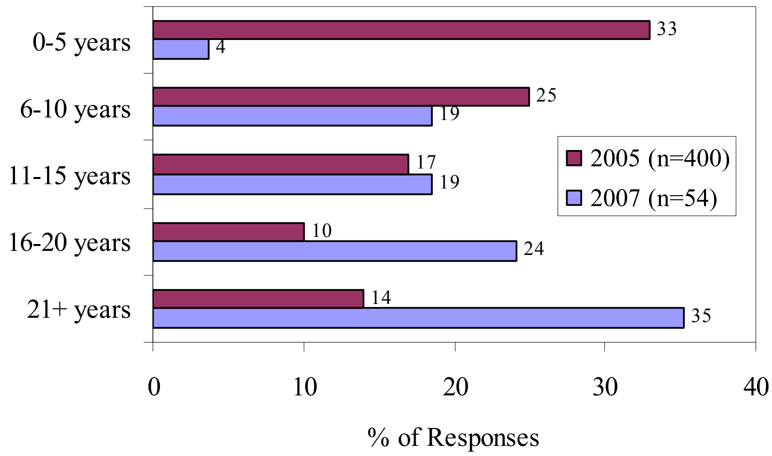

Figure 2 – Age of Capstone Courses
(note, results are as of the year of the survey)

In comparing the respondent pool from the 2005 and 2007 surveys, it is important to recognize that the latter is not a direct subset of the former. Indeed, of the 55 departments in the 2007 respondent pool, only 20 also participated in the 2005 nationwide survey. At an institutional level, the overlap increases; 35 of the 45 institutions represented in the 2007 survey were also represented in the 2005 survey.

3B. Project Logistics

One question on the 2007 survey asked the typical duration of design projects in the capstone course. Figure 3 shows the results of this question, compared with data from the 2005 survey. The 2007 respondents mostly follow the semester system, and the majority have project durations of two semesters. Interestingly, older capstone courses do not necessarily imply longer projects; a correlation of age and duration reveals a breadth of ages across both one and two semester projects. The "Other" category for the 2007 data includes projects that are either 1.5 semesters and a combination of full-time and part-time work across multiple quarters.

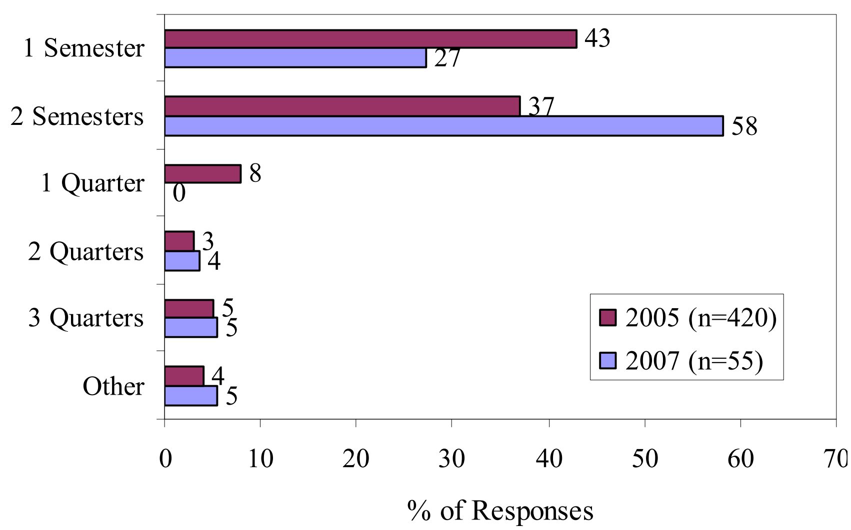

Figure 3 – Duration of Capstone Course Project

Figure 4 shows the number of projects in a capstone course for the 2007 respondents, compared with the 2005 and 1994 results. Of note for the 2007 data is the large response of "16+ projects", coupled with a relatively small response for "1" or "2-5" projects. In fact, the mean number of projects from the 2007 data is 18 and the median is 12, whereas the corresponding values in 2005 were 8 and 5 respectively. The differences from the previous results may be the result of the different respondent populations and/or the fact that faculty with larger capstone programs were more attracted to the capstone conference. The differences may also stem from a difference in question wording: both the 1994 and 2005 surveys asked about "number of projects per course cycle" whereas the 2007 survey asked about how many projects were "run in the most recent offering of the capstone course". Interestingly, unlike the 2005 data,[2] the 2007 data do imply that a larger number of students maps to a larger number of projects, as shown in Figure 5. It is also worth noting that both the data point for the largest number of students (350) and that for the largest number of projects (65) were from institutions outside the U.S.

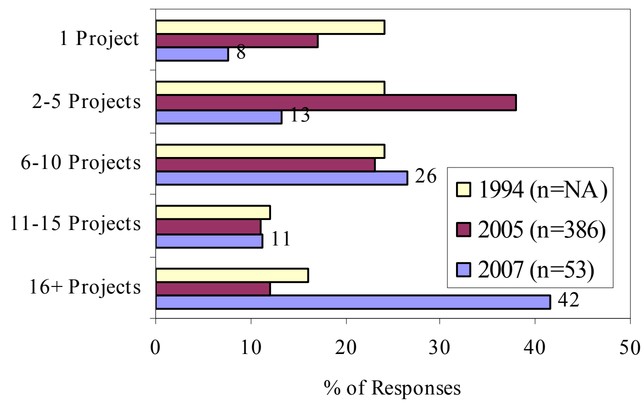

Figure 4 – Number of Projects per Course Cycle/
in Recent Offering

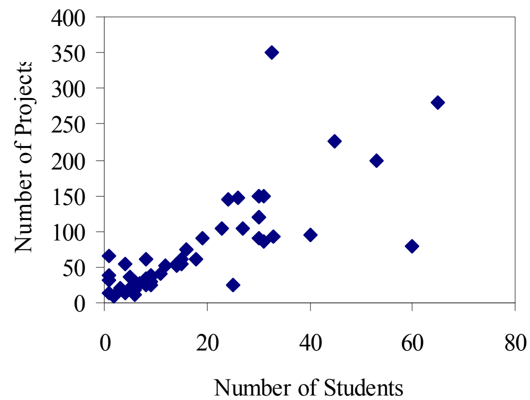

Figure 5 – Number of Projects Versus Number of Students
per Course Offering (n=53)

While the 2005 survey collected data on average number of students per team, it did not record minimum and maximum team sizes. Figure 6 shows these results for the 2007 focused survey. For each response (n=54), the average reported team size is shown as a square data point and marked with lines for the reported minimum and maximum. While a few respondents reported wide variation in team size, the majority did not vary from their reported average by more than 1-2 students in either direction. As noted on the graph, the mean and median of the reported "average" were about 4.

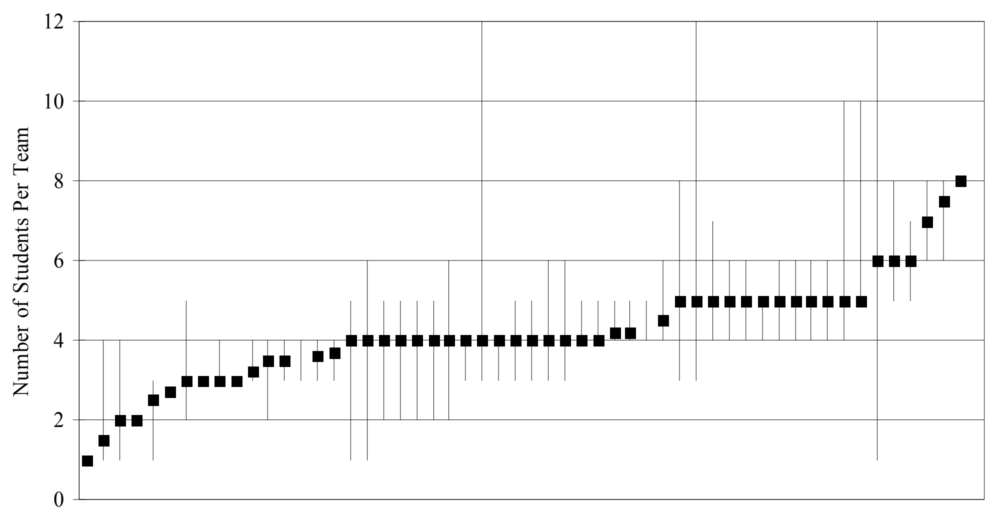

Figure 6 – Number and Range of Students per Team (n=54)

3C. Faculty Credit/Involvement

How capstone courses are counted in terms of teaching credit is an interesting and complex topic, and one that varies significantly across departments and institutions. Since neither the 1994 nor 2005 surveys collected detailed information about capstone credit, the 2007 specifically asked respondents to explain how involvement in the capstone design course is accounted for in terms of teaching load. The responses provided, though not always complete, were quite varied, especially with regard to mentoring capstone design projects.

Some respondents commented specifically about the lecture/course component of their capstone program. Of these responses (n=33), 88% noted that the classroom portion counts as a standard course. Three other respondents noted receiving partial course credit (one-third to two-thirds) for the capstone course, and one respondent remarked that teaching the course does not count at all, though coaching the teams does.

The responses regarding team mentoring/coaching were even more interesting. As shown in Table 1, the responses could be grouped into three main categories: cases where specific course credit was awarded to faculty who coached/mentored capstone design teams, cases where coaching the teams was included with teaching/running the capstone design course, and cases where no credit was awarded for involvement with design teams. (Note, the percentages sum to more than 100% because two respondents reported a hybrid model of the "included" category for the capstone instructor and "no credit" category for other faculty coaches.) Of the 16 respondents who noted receiving "no credit", 7 specifically commented that coaching the design project teams was "expected" as part of the teaching load or departmental service. In the "course credit" category, 17 respondents gave numerical values for the course credit per project; these results are shown in Table 2, divided by project duration. Although Table 2 does not represent very many data points, it does highlight, as one might expect, that faculty receive more teaching credit for coaching longer duration projects. Understanding how capstone course lectures and project coaching are counted, while accounting for the nuances of various departmental and institutional bean-counting, merits further study, perhaps through focused interviews.

Table 1 – Type of Credit for Capstone Design Project Involvement

Type of Credit	**% of Responses (n=43)**
Course Credit	42
Included	26
No Credit	37

Table 2 – Range of Course Credit for Capstone Design Project Involvement

Project Duration	**Course Credit (per complete project)**	**Number of Responses**
1 Semester	0.17 – 0.33 course	3
2 Quarters	0.29 – 0.33 course	1
2 Semesters	0.25 – 0.50 course	10
3 Quarters	1 course	3

The 2007 survey asked respondents how many faculty received teaching credit for involvement in the most recent capstone course offering as well as how many faculty teach in the department. Figure 7 and Table 3 present these data (n=53) in two forms. Figure 7 shows a scatter plot relating total number of departmental faculty to number of faculty receiving teaching credit for capstone involvement. While there is no evident correlation, it is worth noting the many cases in which only one faculty member received credit for capstone involvement despite fairly large total faculty numbers. Table 3 provides the same information in terms of percentage of total faculty receiving credit for involvement. Worth noting are the majority of cases in which 20% or fewer of the faculty receive credit for involvement, coupled with the not-insignificant number cases in which all or nearly all faculty receive capstone credit.

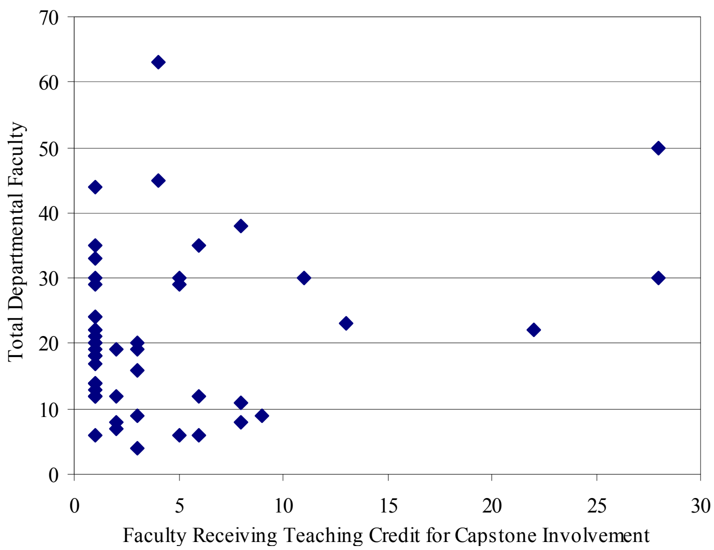

Figure 7 – Total Faculty and Capstone-Credited Faculty (n=53)

Table 3 – Percentage of Total Faculty Receiving Teaching Credit for Capstone Involvement

% of Faculty Receiving Credit for Capstone	**% of Responses (n=53)**
0 – 20 %	70
21 – 40 %	9
41 – 60%	6
61 – 80%	4
81 – 100 %	11

Table 4 presents the student/faculty ratio based on responses about number of students in the capstone course and number of faculty receiving teaching credit for their involvement. Note that the faculty numbers do not necessarily reflect *all* faculty involved with the capstone course, only those who received teaching credit for their involvement. As discussed in Table 1, a sizable minority of programs do not provide teaching credit for coaching design project teams. While the results in Table 4 show that 44% of respondents have student/faculty ratios less than 20, the fact that this ratio is greater than 40 for nearly a quarter of respondents, especially for a design-based course, is striking.

Table 4 – Student/Faculty Ratio for Faculty Receiving Teaching Credit for Capstone Involvement

Student/Faculty Ratio	**% of Responses (n=53)**
1 – 10	19
11 – 20	25
21 – 40	34
41 – 60	8
61+	15

3D. Costs/Funding

One of the goals of the 2007 follow-up survey was to collect specific information about direct project costs and levels of project funding. One question asked about the direct costs per project – average, maximum, and minimum – in the most recent course offering. Figure 8 shows the results (n=50), in order by reported maximum. The reported averages are marked by square data points and the reported maxima and minima marked with lines. So as to better view the small values, the graph is truncated at a direct cost of $15000, and the three reported maxima exceeding this are noted off the graph. Maxima and minima for the set of points on the right of the graph were not reported. As marked on the graph, the mean and median value for reported "averages" were $1279 and $500, respectively. These values and the data overall match the results from the 2005 survey, in which the majority of average direct project costs were between $1-1000 [3]. An additional insight afforded by Figure 8 is that in most cases the reported average direct cost per project is less – and often significantly less – than the midpoint between the reported maximum and minimum, suggesting that the maximum costs are associated with only the occasional project.

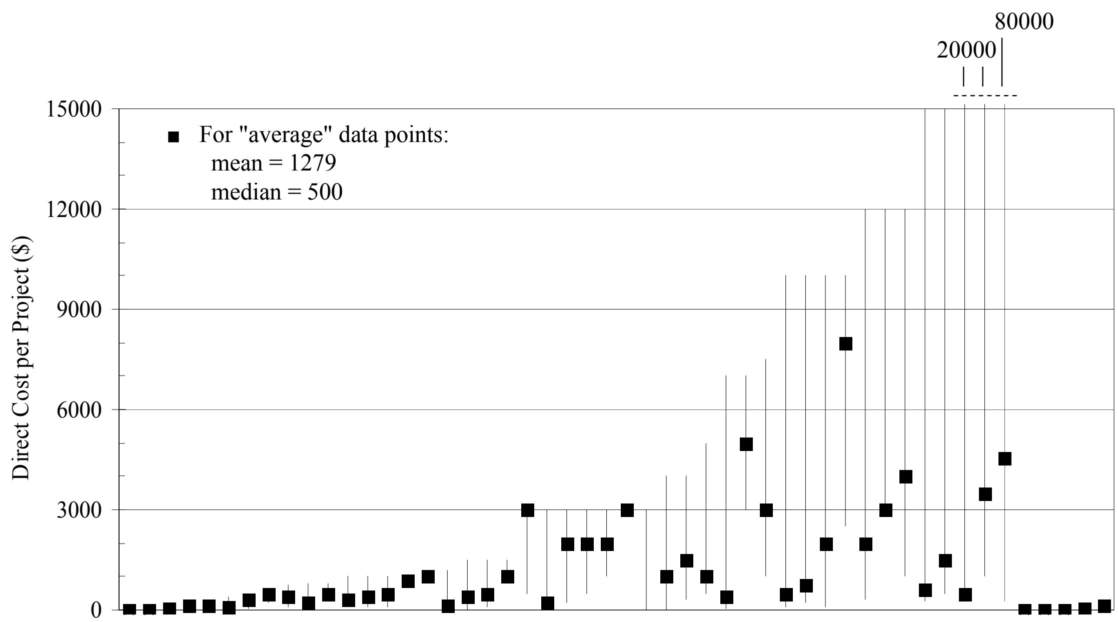

Figure 8 – Amount and Range of Direct Cost per Project (n=50)

To differentiate between expenses and income, the 2007 focused survey asked whether respondents had any externally sponsored projects; 84% (n=55) of the respondents answered yes. Figure 9 shows the results of how much financial support per project the sponsors provided for these respondents, using a similar presentation method to Figure 8. As before, the graph is sorted by reported maximum (n=44), the values exceeding the graph limit are noted, and the reported "average" values on the right of the graph were not accompanied by minima or maxima. The average and maximum reported values of sponsor support are substantially higher than those for direct costs (as noted in Figure 9, the mean and median values of average sponsor support were $4155 and $1000, respectively). At the highest level of maximum sponsor support, the average reported data are very close to the reported minima, suggesting that such significant sponsor support occurs very infrequently. While this pattern is true for some of the other data points, for a number of others the reported average is near the midpoint of the reported maximum and minimum, indicating a variability across projects; similarly, in the 2005 survey, a quarter of respondents noted that average total amount of financial support provided by a sponsor per project was "variable" [2].

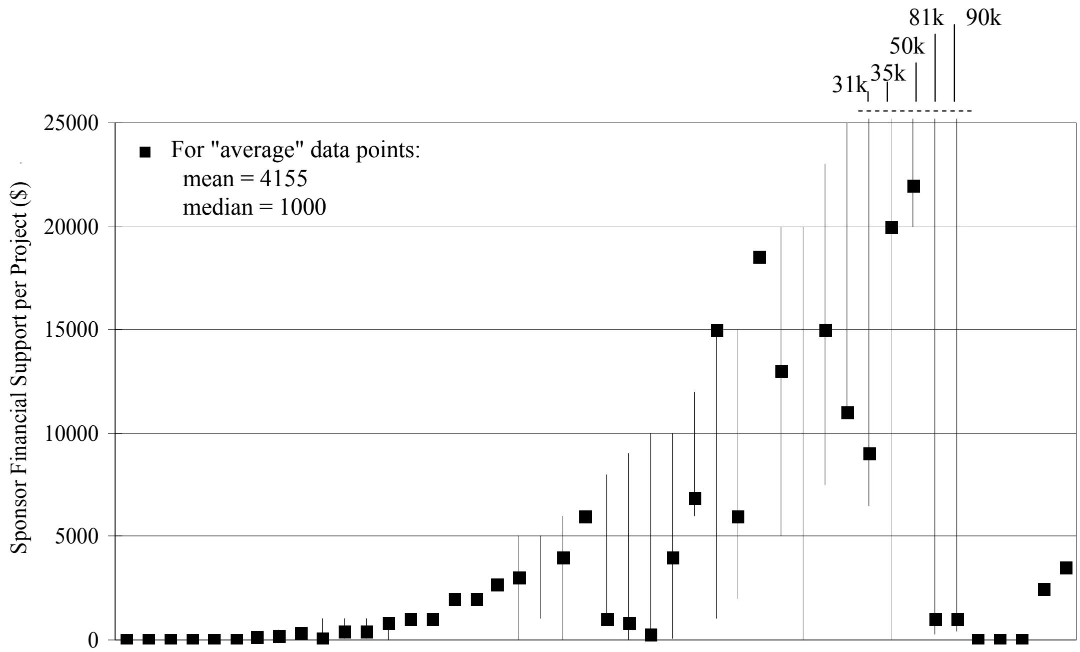

Figure 9 – Amount and Range of Sponsor Support per Project (n=44)

The connection between direct cost and sponsor support per project is shown in Figure 10. The data points (n=38) are organized first by increasing average sponsor support and then average direct cost. An important feature on the graph is that, with a few exceptions, the average sponsor support per project equals or – more often – exceeds the average direct cost per project. Even more strikingly, this difference increases at higher levels of sponsor support. This may suggest that at these higher levels of sponsorship, the support contributes to indirect project costs and/or other departmental or institutional expenses, thus providing benefits far beyond the project itself.

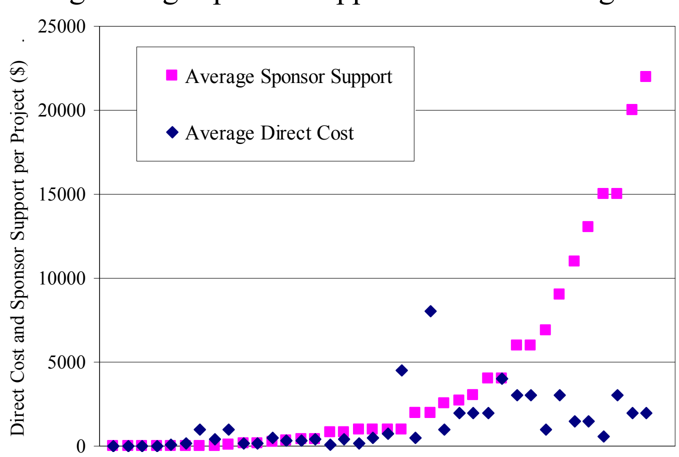

Figure 10 – Direct Cost and Sponsor Support per Project (n=38)

Figure 11 shows the relationship between average sponsor support per project and age of capstone course (n=41). While one might initially think that more established capstone programs generate higher levels of sponsor funding, Figure 11 does not show this to be true. Indeed, the highest levels of sponsor support were received by capstone courses in the younger half.

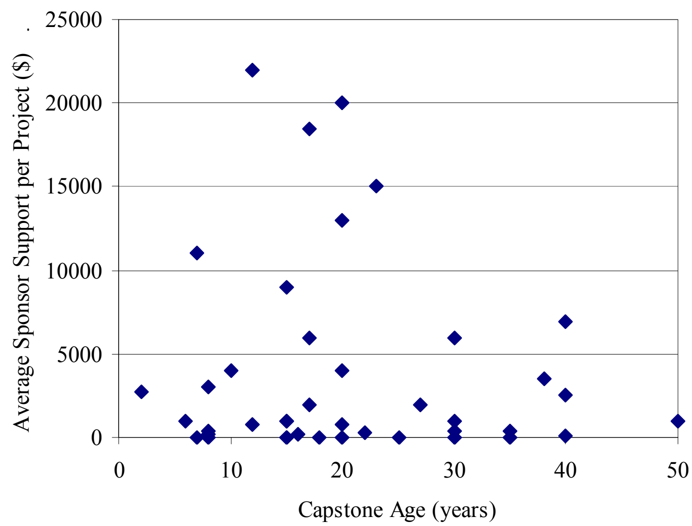

Figure 11 – Sponsor Support and Capstone Age (n=41)

The relationships between the average per project direct costs, sponsor support, and department are shown in Figures 12 and 13. As is clear in both graphs, the mean direct cost and level of sponsor support for CE, ECE, and IE are lower than they are for ME and Other, but all departments exhibit variability in both expense and income. Interestingly, the three highest sponsor support points in the "Other" category are from interdisciplinary capstone programs.

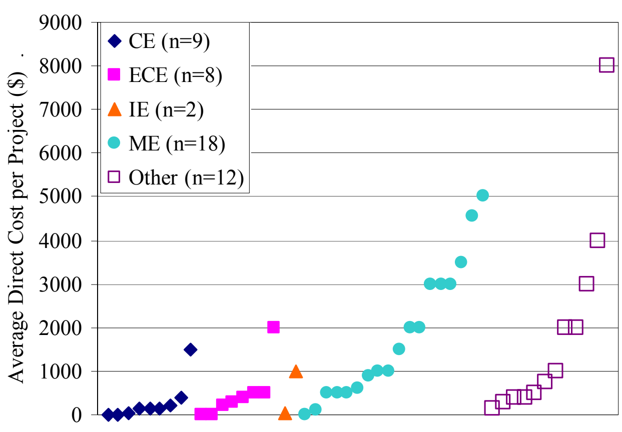

Figure 12 – Direct Cost and Department

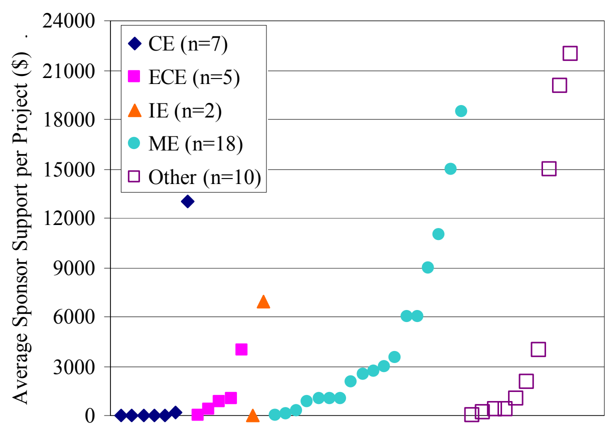

Figure 13 – Sponsor Support and Department

Figures 14 and 15 show the relationships between average per project direct costs, sponsor support, and duration of capstone program, focusing on both 1-semester and 2-semesters capstone courses. While in both graphs the course duration doubles from one to two semesters, the average direct costs and sponsor support at least treble; indeed, the mean sponsor support value increases by a factor of three and the mean direct cost value increases by a factor of four. One theory underlying the direct cost data is that the complexity of projects that can be completed in two semesters is more than double the complexity for a corresponding one semester duration and that more complex projects incur higher costs. Another possibility is that the two semester timeframe expands the design iteration phase, enabling more prototypes to be built and tested, thus increasing costs. Higher sponsor support for two-semester courses may be related to increased project complexity; sponsors may be willing to pay more and/or departments may be able to charge more for increased complexity or completeness.

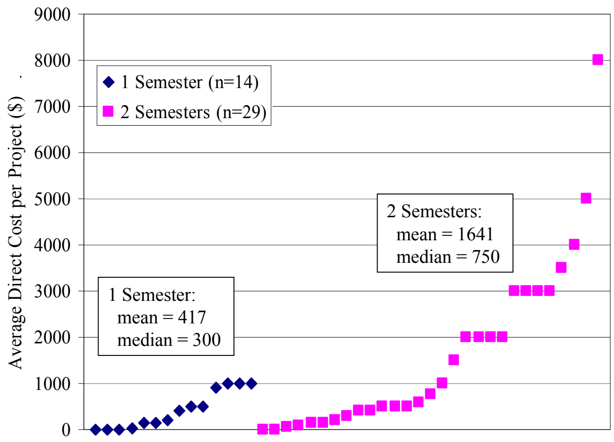

Figure 14 – Direct Cost and Capstone Course Duration

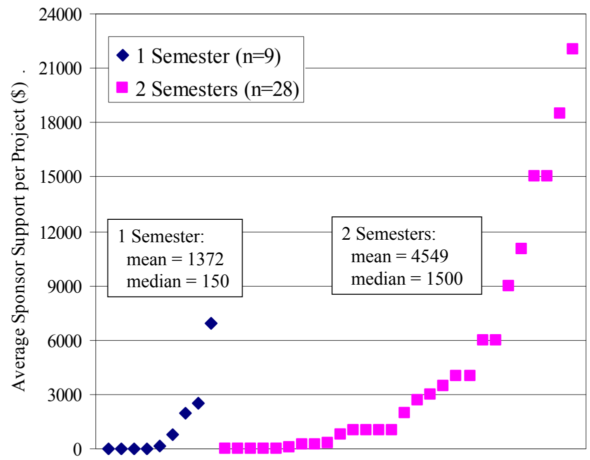

Figure 15 – Sponsor Support and Capstone Course Duration

4. Conclusions

This work discusses responses from a focused survey on capstone design courses conducted in 2007. The survey was distributed in paper form to the audience for the opening keynote session at the inaugural National Capstone Design Course Conference in June 2007. The survey received responses from 59 participants, representing 55 distinct departments from 45 institutions. Highlights of the results, divided by the sections in this paper, are reviewed below:

- Respondents: The survey respondents represented a distribution of departments but were missing chemical engineering and had an emphasis in mechanical engineering. The majority of capstone courses were 16 years or older.

- Project Logistics: The majority of respondents' capstone design projects spanned a duration of two semesters. The 2007 responses revealed a larger number of projects (median=12, mean=18) per course than did previous survey data and also showed a correlation between number of projects and number of students. Mean and median team size was about 4 with variation of 1-2 students or less.

- Faculty Credit/Involvement: For the classroom portion of capstone courses, the vast majority of respondents received course credit for teaching the classroom portion, but for project coaching, responses were divided between receiving some credit (1/3 course per completed project, on average), having project coaching included with teaching the class, and receiving no credit. For most respondents, less than 20% of the faculty received teaching credit for capstone involvement. Nearly a quarter of respondents noted a student/faculty ratio greater than 40 for faculty receiving capstone teaching credit.

- Costs/Funding: In accord with previous survey data, the reported average direct costs for capstone design projects had a mean of \$1300 and a median of \$500. Most respondents noted having externally sponsored projects; the mean and median reported average level of sponsor support were $4300 and $1000 respectively, but varied considerably within given courses. In most cases, average sponsor support exceeded direct project costs and sponsor support was not evidently correlated with age of capstone course. Project costs and sponsor support were highest, on average, for respondents from mechanical engineering and "other" engineering departments, including interdisciplinary programs. On average, two-semester projects cost four times that of one-semester ones, and garnered thrice the sponsor support.

This work was motivated by a desire to better understand engineering capstone courses and practices employed by capstone educators, particularly with regard to teaching credit, direct project costs, and sponsor support. The 2007 survey builds on both the 1994 [1] and 2005 [2,3] surveys, providing specific details not captured by its predecessors. While the data from all three surveys identify many patterns and trends, the variability of responses across department, institution, and time emphasizes the diversity of capstone programs; there clearly is no predominant capstone implementation. Continued study of the variety of current capstone practices and their effectiveness will enable advancement and improvement of the entire community of capstone programs.

5. Acknowledgements

I gratefully acknowledge the attendees of the 2007 National Capstone Design Course Conference who contributed their time and responses to the 2007 survey, as well as the keynote audience as a whole for their interest in and lively discussion of the previous capstone survey work. I also extend special thanks to Amanda Lapahie for assistance with processing the 2007 survey data.

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