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Where Are We Now? Statistics on Capstone Courses Nationwide

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ABSTRACT

Capstone design courses are an increasingly common component of engineering curricula nationwide, but how much do we really know about the current practices? How do capstone courses differ across departments and institutions? How have capstone courses changed in the past 10 years? This paper highlights data from a survey of engineering capstone design courses conducted in 2005, based on responses from 444 programs at 232 institutions. Particular focus areas include respondent profile, course/project logistics, faculty involvement, funding details, industry sponsorship, and success. The 2005 data are also compared with results from the comparable survey by Todd and Magleby et al. in 1994 (*Journal of Engineering Education*, April 1995), thus providing both a snapshot of recent practices plus an indication of trends over the past decade.

INTRODUCTION

Capstone design courses offer engineering students a culminating design experience on an applied engineering project. With a longstanding history reinforced by support from the Accreditation Board for Engineering and Technology (ABET), these courses have become common in engineering departments across the United States. The composition of capstone courses, however, varies widely. In 1994, Todd et al. [1]–[3] conducted a survey of engineering departments throughout North America to capture educational and logistical practices in capstone design courses at the time.

The 2005 follow-up survey was conducted to collect current practices and examine trends in the past decade. The survey included the questions of its 1994 predecessor, augmented with further questions on course management, student deliverables and evaluation, and program funding. Direct comparisons between the results of the 2005 survey and results from the same questions on the 1994 survey were presented at ASEE 2006 [4]. Results from the additional questions on the 2005 survey were presented at FIE 2006 [5]. Highlights from these two publications, combined with additional correlations across program age and department, were presented in the opening keynote session of the 2007 National Capstone Design Course Conference (hereafter referred to as the 2007 Capstone Conference). This paper directly reflects the information presented in the keynote session and, as such, draws heavily on the previous ASEE [4] and FIE [5] publications. As in the previous papers, the data provide further insight about the current state of engineering capstone education. The results of the survey are a first step in understanding, assessing, and ultimately improving engineering capstone education nationwide.

SURVEY METHODS AND RESPONDENTS

The 2005 survey was designed to include most of the questions in its 1994 predecessor [1] plus some additional detailed questions, and was refined based on feedback from several colleagues in capstone education. The final version with seven sections and a total of 57 questions was posted online. Following a cover page soliciting contact information for the respondent, the survey questions focused on course details, faculty involvement, project information, feedback from course participants, project funding, and industry sponsorship. A page was devoted to any further comments from respondents, with several open-ended questions. (See http://www.smith.edu/engin/designclinic/capstonesurveyresults2005.html and click on "2005 Capstone Survey" to download the survey in pdf form.)

In May 2005, we sent an email to the department chair of each accredited undergraduate engineering program in the United States, asking that it be forwarded to the person in charge of each capstone course. If the program had no capstone courses, the department head was asked to indicate this on the initial page, and submit that page. Names and contact information for these programs had been compiled earlier using ABET's online listing of accredited engineering programs as of fall 2004 [6]. We sent a follow-up email in June 2005 to all those who had not yet responded, then another in October 2005 to a targeted group of still non-responding institutions: ranked schools from U.S. News and World Report [7, 8]. Responses were accepted until early November 2005.

Of the 1724 programs at 350 institutions surveyed, 444 programs from 232 institutions replied, yielding response rates of 26% among programs and 66% among institutions. The results of the online survey (responses plus comments) were compiled and processed electronically. Of the 444 respondents, 98% offered some form of capstone design course or project. Table 1 summarizes the numbers for the accredited ABET list (as of fall 2004), the 2005 survey respondents, and the 2007 Capstone Conference attendees to provide context for the numbers. Note that while the 2005 survey did not capture every ABET program nor every attendee at the 2007 Capstone Conference, the survey data provide the most broad and most current information to date on capstone programs nationally.

SURVEY RESULTS AND DISCUSSION

This section details and discusses the results of the 2005 survey, both as stand-alone data and in comparison with the relevant 1994 results. The data are organized into five main categories following the order in which they were presented at the 2007 Capstone Conference: survey respondents, course/project logistics, faculty involvement, funding details, and industry sponsors. Where applicable, discussion areas from the 2007 Capstone Conference audience are included.

A) Survey Respondents

Figure 1 shows the number of respondents sorted by department. The specific categories were chosen for ease of comparison; departments were grouped as closely as possible. Note, that since many departments represent several related disciplines, the categories represented more than just

	Departments	Institutions
ABET Accredited List	1724	350
2005 Survey Respondents	444 (26% response rate)	232 (66% response rate)
2007 Capstone Conference Attendees	114 (44% represented in 2005 survey)	84 (83% represented in 2005 survey)

Table 1: Context for Capstone Numbers.

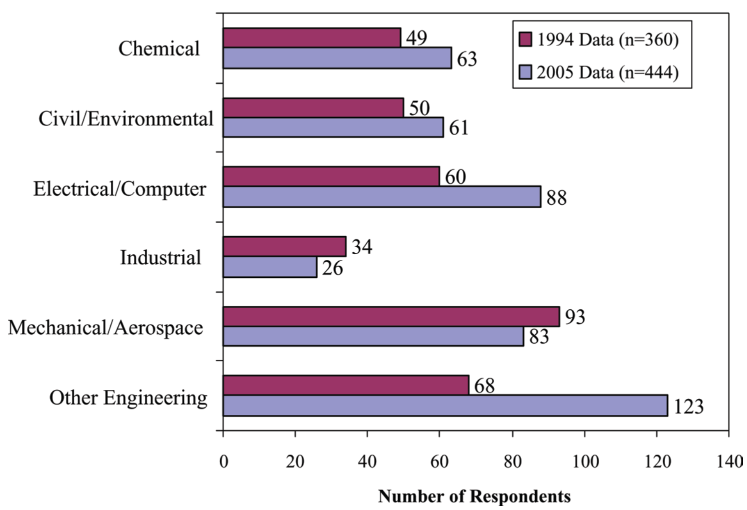


Figure 1: Number of Respondents by Department.

the listed department. For example, “Chemical” included pure chemical engineering departments, as well as chemical and biomolecular, chemical and biological, and chemical and biomedical. Pure biomedical engineering departments, on the other hand, were grouped in “Other Engineering”. Similarly, some of the “Civil/Environmental” departments included architecture or surveying and some of the “Industrial” departments included manufacturing or systems. The “Other Engineering” category included such departments as biomedical, geological, materials, mining, nuclear, and petroleum engineering as well as general engineering (15% of the “Other Engineering” category). As is clear from Figure 1, the respondent populations for both the 1994 and 2005 surveys spanned across the disciplines, with no single discipline overwhelming the others. The substantial increase in “Other Engineering” departments responding to the 2005 survey likely reflects the rise of specialized, interdisciplinary, and general engineering departments in the past decade [9]. Note that, across departments, an average of 28% of 1994 respondents also responded to the 2005 survey.

The age of respondents’ existing capstone courses, listed in Table 2, shows a similar variety, though respondents tended slightly more to represent fairly recent capstone courses. In fact, over half of the capstone courses were less than ten years old (in their current form), while nearly three-quarters were initiated after 1990. Perhaps most notable is that 33% of the existing capstone courses were five years old or less in 2005. The total range is also extensive. The youngest two capstone courses, from both a biomedical and an industrial engineering program, were reported as six months old in 2005, while one mechanical engineering department offered one that was 80 years old. Figure 2 displays this capstone age data by department. Half of responding CE departments and nearly half of responding EE departments had existing capstone programs that were five years old or less. Most departments were weighted toward younger aged capstone programs, except for CHE, which shows the opposite trend; more than a quarter of responding CHE existing capstone programs were 21+ years old in 2005. Note that in providing data about the age of their capstone programs, respondents were answering the survey question “How long has this course been in existence in its present form?” Discussion at the 2007 Capstone Conference suggested that the younger aged data may also reflect departments who had recently changed their longstanding capstone programs, thus yielding a reduced age in “present form”.

B) Course/Project Logistics

Figure 3 shows the capstone course team structures the respondents use (n = 417 for 2005). Note that the responses sum to more than 100 percent since respondents could select more than one option. As was true in 1994, the vast majority of departments in 2005 still organized students around departmental teams. It is interesting to note, however, the decrease in individual teams as well as the increase in interdepartmental teams, suggesting that departments were emphasizing teamwork and increasing opportunities for cross-disciplinary collaboration. Many of the respondents who selected "Other" commented that they had either multiple capstone courses in their department and/or a sequence of design courses that spanned more than a single year.

Figure 4 depicts the structure and sequence of the capstone course, with regard to class and project (n = 414 for 2005). The majority of respondents in 2005 offered a capstone course in parallel with design project(s), as did the majority in 1994. The change in data, however, suggests an increase in this approach coupled with a decrease in separate "class then project" or "project only" approaches. Capstone courses without a project component were, as before, a very small minority. Regarding the instructional component, some of the respondents commented that their courses had formal instruction in the first few weeks and more informal meetings thereafter, while others noted having occasional instruction as needed throughout the course. Some respondents specifically mentioned using class time for students to meet with clients/advisors and to present informally to their peers.

Age Range (years)*	% Responses (n=400)
0-5	33
6-10	25
11-15	17
16-20	10
21+	14

* Note, responses are as of 2005.

Table 2: Age of Capstone Programs.

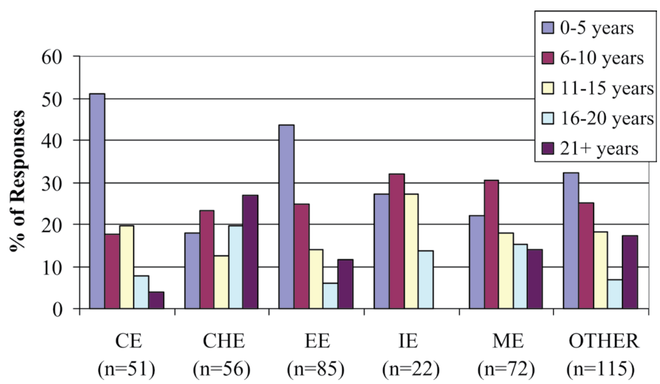


Figure 2: Age of Existing Capstone Course by Department.

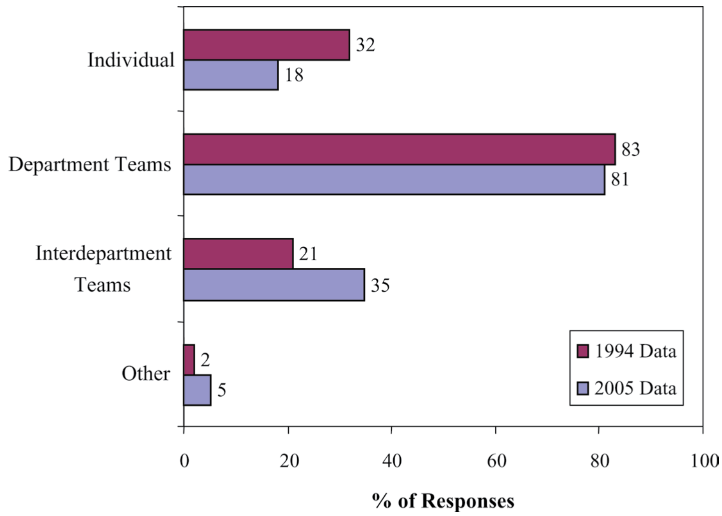


Figure 3: Capstone Course Team Structure.

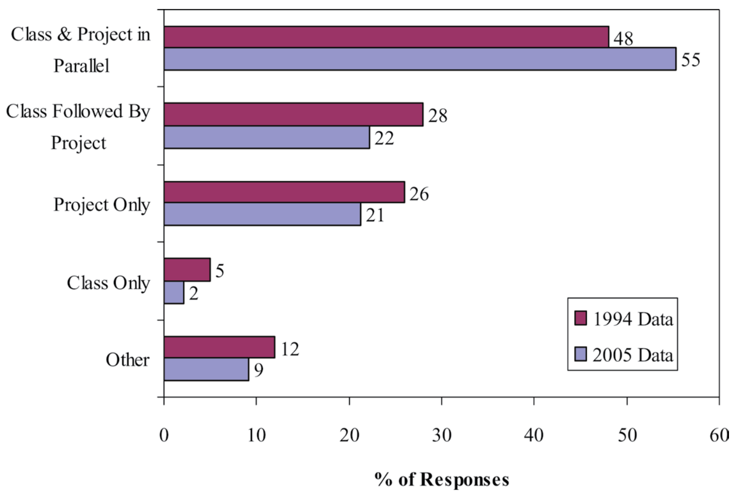


Figure 4: Capstone Course Sequence and Structure.

Figure 5 provides the data for the duration of both the capstone course and project. The 1994 data are reported with the course and project responses combined, whereas the 2005 data (n = 420) report them separately. Overall, the data do not show a sizable change over the past 10 years; the majority of respondents offered their capstone courses as either a one-semester or two-semester option. Responses from the “Other” category ranged from courses only a few weeks long to those

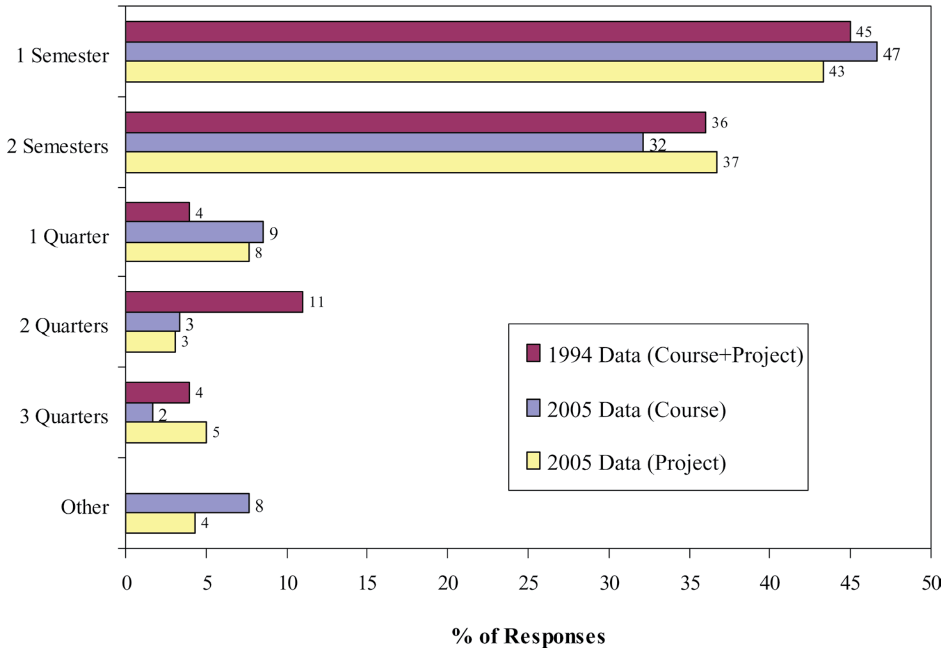


Figure 5: Duration of Course and Project.

running three or more semesters, and projects that started mid-semester or were combined with other smaller projects.

What topics are taught in capstone courses? In the 2005 survey, respondents were asked to select from a list of 23 different topics (plus a "write-in" option) what they included in their classes. Table 3 lists the results from the 2005 survey compared with the most frequently taught subjects reported from the 1994 survey. The topics marked with a (*) were also included in the 1994 survey. Responses for the "Other" write-in option included another 75+ topics, ranging from material selection to poster communication to corporate culture. The values in the table sum to far more than 100%, indicating that most respondents selected multiple options.

One result evident from the data in Table 3 is that the subjects reported as most frequently taught in 1994 were even more frequently or at least as frequently taught in 2005. In addition, several topics added to the 2005 survey, such as written communication, decision making, and leadership, proved to be widely taught subjects. Finally, it is interesting to note the type of topics reported as most frequently taught in 2005; professional skills were the majority of topics taught by 50% or more of the 2005 respondents. As encouraged by ABET's Engineering Criteria [10] and exemplified in many engineering programs [11], professional skills are an important component of engineering education, and the capstone experience is one place in which they are prevalent.

1994 Survey Responses +		2005 Survey Responses (n = 343)	
Topic	%	Topic	%
Oral Communication	61%	Written Communication	87
Drawings/Creativity/Concept Generation	48%	Oral Communication*	83
Teamwork Essentials	44%	Engineering Ethics*	76
Planning/Scheduling	42%	Project Planning and Scheduling*	72
Engineering Ethics	40%	Decision-Making	68
Engineering Economics	40%	Teambuilding	66
Developing/Writing Functional Specs	36%	Team Dynamics	63
Safety in Product Design	33%	Engineering Economics*	61
Optimization	31%	Developing/Writing Functional Specs	56
		Safety in Product Design*	52
+most frequently taught topics from 1994 survey,		Leadership	50
as reported in *JEE* [3] (full list for 2005 survey)		Standard and Regulations*	49
*2005 survey topics repeated from 1994 survey		Drawings/Creativity/Concept Generation*	48
		Analysis Tools*	46
		Intellectual Property/Patents	45
		Prototyping and Testing*	37
		Optimization*	34
		Sustainability	29
		Manufacturing Processes*	29
		Risk Assessment	29
		CAD Design and Layout*	29
		Product Liability*	24
		Quality Function Deployment*	17
		Other	13

Table 3: Topics Taught in Capstone Courses.

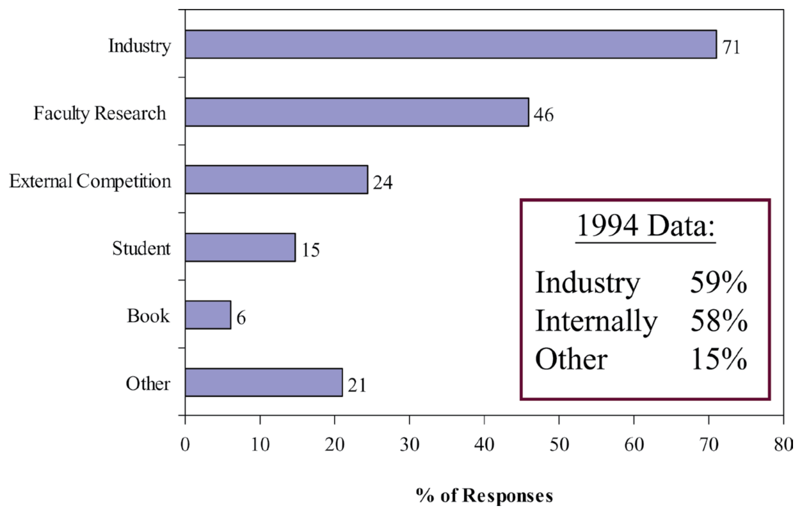


Figure 6: Sources of Capstone Projects.

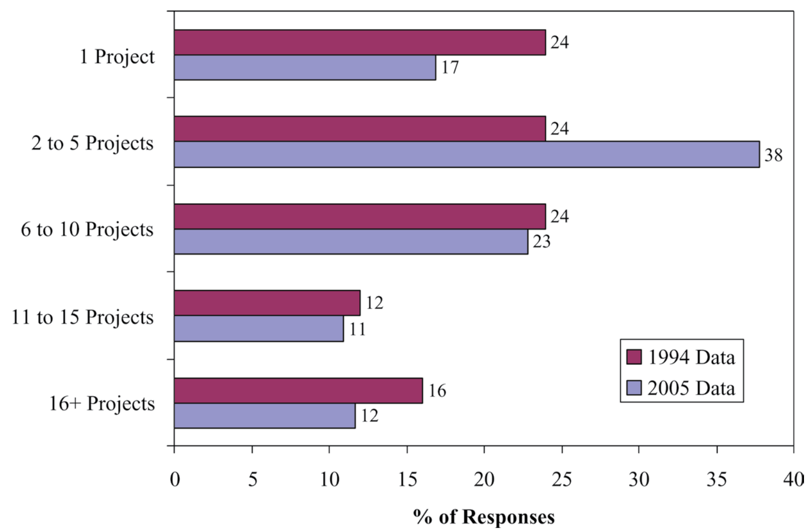


Figure 7: Number of Projects per Course Cycle.

Most commonly, the course component of capstone programs was supplemented with projects. The source of those projects, however, varied widely. Figure 6 shows the results of project source from both the 2005 and 1994 surveys, separated to reflect the different wording on the two surveys. While project sourcing was evenly matched both industrially and internally in 1994, the 2005 data (n = 394) show a decided shift toward external project sourcing, with industry at 71% and external competitions at 24%. Interestingly, while many respondents to both surveys selected multiple answers to the question, 30% of 2005 respondents indicated that projects were obtained from only one source. Of those who selected only one option, industry was the most frequent choice. Respondents who checked "Other" noted multiple project sources, including course instructors and other faculty (often either made-up projects or ideas based on industry experience), community or local government, other non-profit organizations, and university IP.

Figure 7 shows the number of projects per course cycle. A comparison of the 1994 and 2005 data (n = 386 for 2005) reveals a sizable increase in the 2–5 project range accompanied by a decrease in both the single project and the 16 or more projects range. Note for the 2005 data, the average number of projects per capstone program was 8.1 and the median is 5.0.

Figure 8 illustrates the number of students per team. In the 2005 data (n = 377), the "1" response refers to a response of exactly 1, whereas the "1 to 3" range includes all responses ≥1.5 and <3.5. Similarly, the other ranges include rounded values as well (i.e. the "4 to 6" range includes all values ≥3.5 and <6.5). When respondents reported ranges (such as "1–4"), their inputs were averaged and the resulting value was categorized accordingly. The fact that there are so few reported single person teams in 2005 does not imply that almost no departments utilized single person teams (a result that would conflict with the data in Figure 3), but rather that only very few departments utilized *solely* single person teams. Since respondents were asked to report the average number of students per team, the presence of multi-person teams increased their average to more than 1. This is in keeping with the data behind Figure 3, in that only 2% of those respondents selected *only* the "Individual" option. While the overall distribution of the 2005 data is similar to that of the 1994 data, the sizable increase in 4 to 6 person teams and the corresponding decrease in 1 to 3 person teams are worth

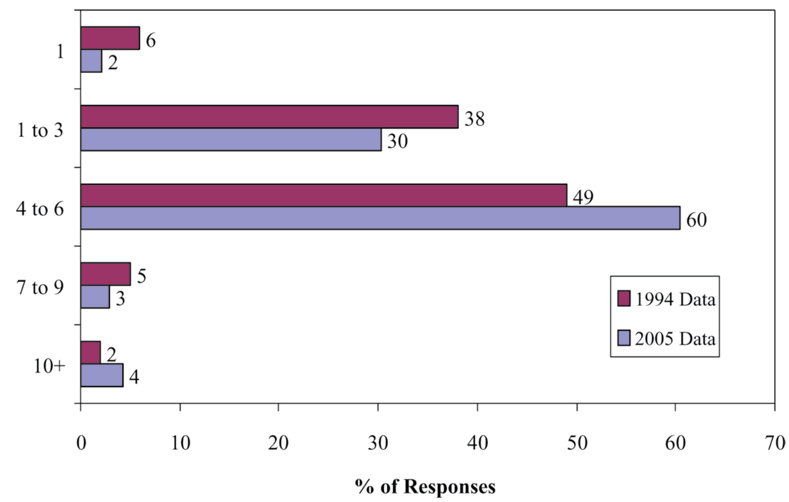


Figure 8: Number of Students per Team.

Response to "How do you ensure that student groups are able to meet and work on the project?"	% Responses (n=414)
Arranging group work time is entirely the student's responsibility.	39
Capstone course includes a lab section specifically for working on the project.	36
Some part of a lab section is set aside for group work on project, but students are responsible for finding other meeting times.	27
Other	15

Table 4: Methods to Ensure Student Meeting/Working Time.

Type of Student Presentation	% of Responses (n= 392)
Informal Interim Presentation	59
Formal Interim Presentation	56
Formal Final Presentation	92
Design Review	45
Other	18

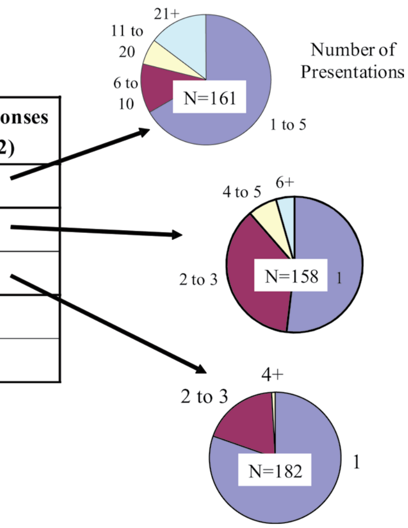
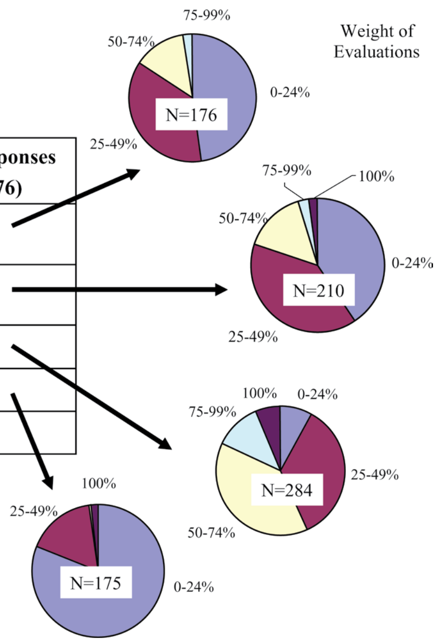


Figure 9: Type and Number of Student Presentations.

noting. These trends suggest an increased emphasis on teamwork, particularly in medium-sized teams, and may reflect an increased complexity of capstone projects, since the duration of capstone courses (see Figure 5) had not changed substantially from 1994 to 2005.

Another question on the 2005 survey focused on how a program ensures students were able to meet and work on the project. As Table 4 shows, respondents were evenly divided between leaving meeting times entirely up to the students, scheduling a specific laboratory section, or using a combination of the two. Comments written in suggested attempts to demand responsibility but provide support: most stated that the students must take initiative to meet, but also indicated that time was built into the general schedule of capstone students. The most common response for the "Other" category was weekly meetings with instructor or faculty advisor. Some responding programs alternated formal instruction periods with "free" days, or arranged for blocks of time when no classes could be scheduled.

Within the course itself, the capstone programs surveyed have explored seemingly endless combinations of presenting and evaluating student work, to the extent that methods of assessing student progress become difficult to categorize. Varied interpretations of the 2005 survey questions may have blurred the categories further. For instance, one question asked about the type and number of student presentations. Responses are shown in Figure 9, with types of presentations in the table and quantities of those presentations in the pie charts. It is interesting to note that 8% of respondents had no formal final presentation, while a few programs arranged for more than



Type of Evaluation	% of Responses (n= 376)
Evaluation of individual deliverables throughout the term	53
Evaluation of group deliverables throughout the term	67
Evaluation of final group deliverable	86
Evaluation by other team members	57
Other	31

Figure 10: Type and Weight of Evaluations.

four per team. Those who marked “Other” noted variability between groups, and several said they placed emphasis on written reports rather than presentations. However, one cannot present this data without considering that a “formal” presentation may have meant an in-class progress report to one respondent, and a campus-wide showing to another.

Another question on the 2005 survey asked about determining final grades for individuals working in teams. Responses in the table in Figure 10 show which factors were considered in the final grade; the weights of the evaluations are shown in the pie charts.

Peer evaluations, as well as evaluations of individual and group deliverables throughout the term were each used by about half of programs. The reportedly common practice of evaluating intermediate and final group deliverables is consistent with findings by McKenzie et al. [12], but a notable finding is that 14% of respondent programs in 2005 did not use evaluations of final group deliverables at all. A surprising theme shown in the pie charts is the number of programs that gave full weight to a single factor. Some based final grades on only group deliverables, while 2% based grades solely on group evaluations. Written comments suggested that attendance, class participation, and evaluations by industry members often affected grades, while some noted specifically that grades were subjective evaluations rather than precisely categorized numbers.

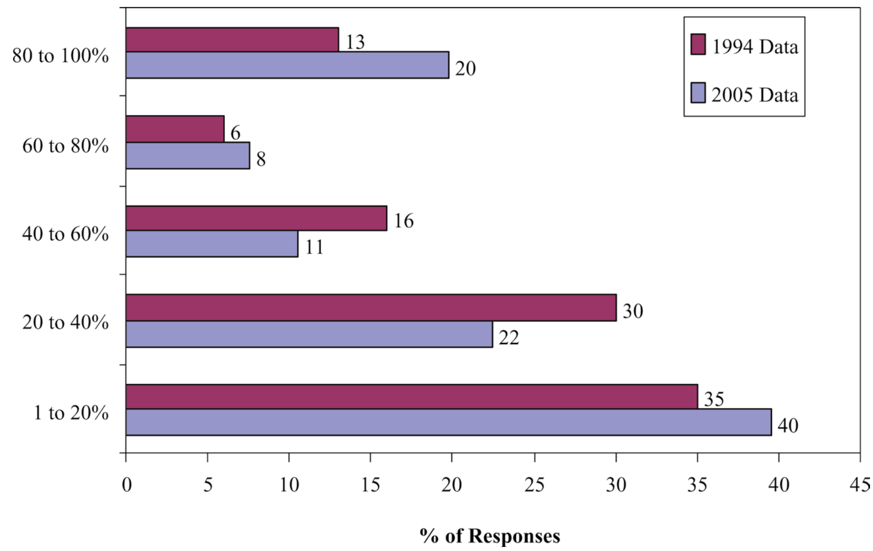


Figure 11: Percent of Faculty Involved in Capstone Experience.

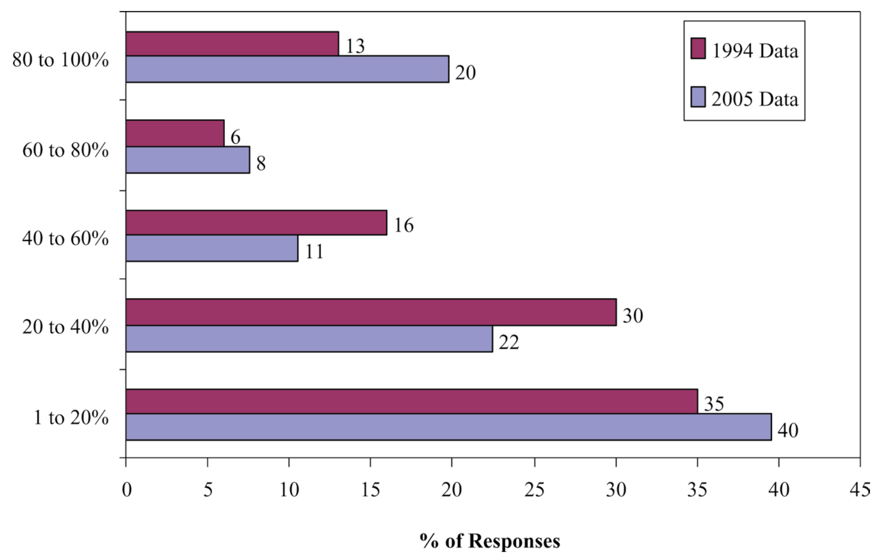


Figure 12: Percent of Faculty Involved in Capstone Project and Formal Instruction.

C) Faculty Involvement

Figure 11 shows the faculty involvement in capstone experience. The 2005 data (n = 369) are based on the reported number of faculty involved in the capstone course as a fraction of the total number of faculty in the department. While the overall distribution of the 2005 data is similar to that from 1994, the increases in the extreme ends (1–20% and 80–100%) are interesting, maybe signifying a bifurcation of departmental approach to capstone involvement. A full 16% of departments responding in 2005 involved 100% of their faculty in their capstone experience.

In addition to reporting the number of faculty involved with capstone courses overall, many 2005 survey respondents also indicated the number of faculty involved in the project component and the formal instruction, as two distinct options (n = 348 for project and n = 304 for formal instruction). Figure 12 shows the comparison results for involvement in both project and formal instruction involvement. Project data follow a similar distribution to overall course (see Figure 11), with the majority of departments involving either <40% or nearly all their faculty. Given the nature of most college courses, the fact that 79% of respondents involved one or very few faculty in the formal instruction is not surprising; worth noting is the small, but not insignificant, number who involved 20–100% of their faculty even in the instructional component.

Tables 5A and 5B show the faculty involvement results from Figure 11 correlated with program age and department. The "average" columns represent the average of different survey responses in each group; the minimum and maximum represent the smallest and largest response for each given set of responses. Note that the percentage of faculty involved ranges from less than 6% up to 100% for all categories (different age groups and different departments). The average percentage varied little by capstone age, ranging from 38 to 44%. More variability is evident by department; CHE had the lowest average percent of faculty involved at 25% and EE had the highest at 49%.

Given that, on average, multiple faculty are involved in the capstone experience, a logical follow-up question is how faculty are compensated for their involvement. Figure 13 shows the results of an open-ended question on the 2005 survey that asked "How is faculty time compensated?" and provides some representative responses. Of the 265 respondents for this question, 65% explained that they received normal teaching credit or course release for being involved. A sizable minority,

Table 5A	% of Faculty Involved		
Age (years)	Avg	Min	Max
1–5 yrs (n=49)	42	2	100
6–10 yrs (n=55)	42	4	100
11–15 yrs (n=72)	38	4	100
16–20 yrs (n=21)	41	6	100
21+ yrs (n=64)	44	2	100

Table 5B	% of Faculty Involved		
Department	Avg	Min	Max
CE (n=49)	44	5	100
CHE (n=55)	25	5	100
EE (n=72)	49	4	100
IE (n=21)	31	3	100
ME (n=64)	41	2	100
Other (n=102)	46	3	100

Tables 5A and 5B: Percent of Faculty Involved by Capstone Program Age (5A) and Department (5B).

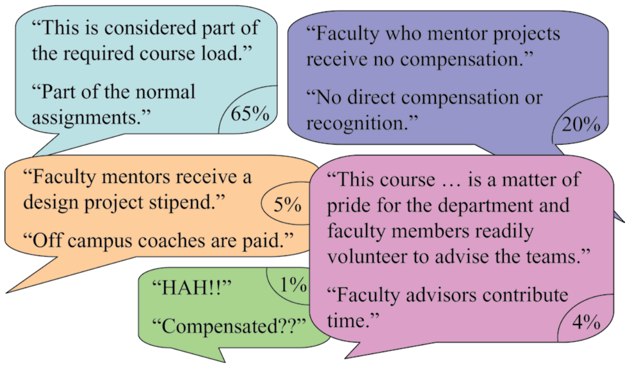
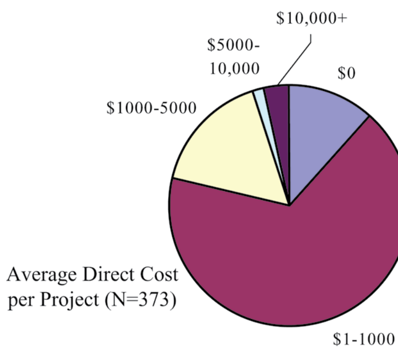


Figure 13: Compensation for Faculty Time.



What Direct Costs Cover

Response Choice	% Responses (N=318)
Supplies	63
Hardware	55
Software	36
Travel	26
Other	26

Figure 14: Direct Project Costs.

20%, noted that they received no compensation, whereas only 5% said that mentors or coaches received any funding. Those who expressly volunteered their time constituted 4% of the respondents; 1% of responses were categorized as “cynical”. The chortling yet affirmative response of the 2007 Capstone Conference audience to these data, especially the cynical category, implies that faculty compensation—or at least accurate assessment and reward for faculty participation—is a subject worth further investigation. Additionally, several members of the 2007 Capstone Conference audience suggested that future survey work should capture whether faculty participating in capstone programs are adjunct or tenure track and whether their backgrounds are academic or industrial.

D) Funding Details

The pie chart in Figure 14 provides data about average direct project costs from the 2005 survey. As shown in the pie chart, 67% of respondents reported that their average direct cost per project ranged from $1 to $1000, while only 5% reported average direct costs above $5,000. Comments written in throughout the survey suggest that many capstone courses did not involve a physical end product, but a more conceptual solution. As shown in the affiliated table, many respondents selected multiple categories when asked what the direct costs cover. Supplies and hardware were the most popular. Software and travel also factored into direct cost for many respondents, while miscellaneous costs such as printing, phone calls, and laboratory fees were listed by those who checked "Other". The survey also asked for percentage of direct cost devoted to each source, with interesting results: software, supplies and travel tended to represent less than one-third of direct cost, while hardware was most often the largest expense. Every category also contained a small percentage of respondents for whom that category represented their entire direct cost.

Figures 15 and 16 show the direct cost data from the 2005 survey correlated with age of capstone program and department. In both cases, the data follow a similar pattern without large differences across either age or department. Although the numbers were small for IE respondents, it is interesting to note that CHE and IE had the largest percentage of zero direct cost projects, but also had projects incurring costs of $10,000 or more.

Sources of project funding are illustrated in Figure 17. In both 1994 and 2005, the institution was the most frequent provider. Students in 2005 paid for projects in fewer of the responding programs than they did in 1994; outside sponsors, however, retained a fairly constant role, funding at least some projects for approximately half of the respondents. Comments from 2005 respondents noted alumni gifts, grants, and departmental budgets as other sources of funding. The more substantial increase in respondents who marked "Other" may be a result of alternate funding sources, but may

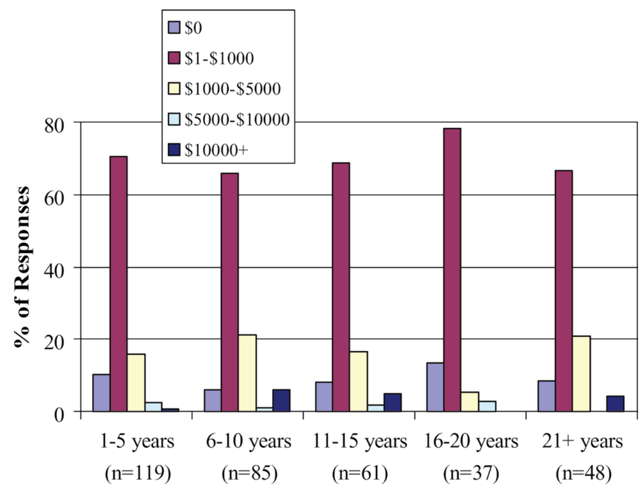


Figure 15: Direct Cost and Capstone Age.

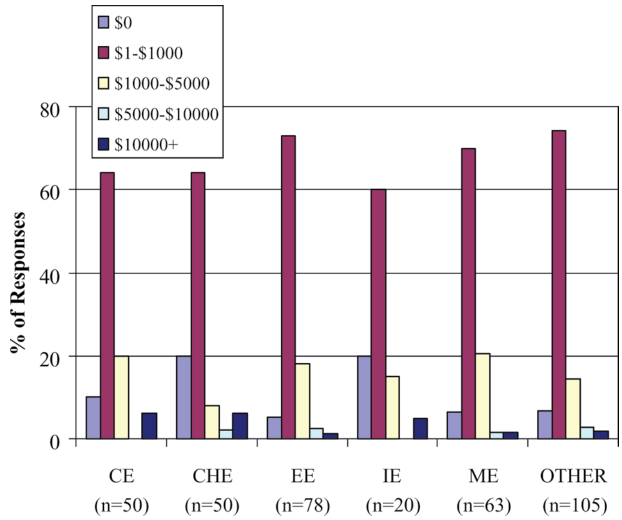


Figure 16: Direct Cost and Department.

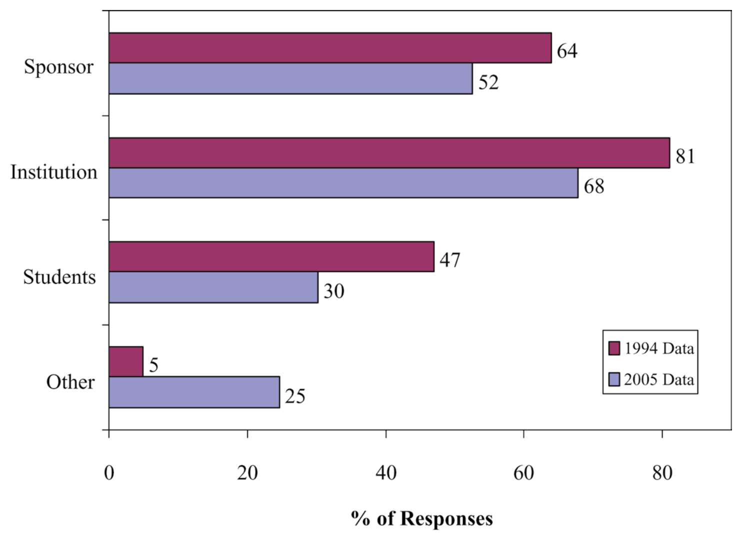


Figure 17: Sources of Project Funding.

also be due to differences in the pools of respondents in both 1994 and 2005. As shown in Figure 1, the 2005 survey included fewer respondents from mechanical and industrial engineering and more from chemical, computer, and “other” engineering disciplines than did the 1994 survey; the design projects for these non-manufacturing departments may not have included a physical/built final product, so may have incurred lower costs. (The wording of the two questions reflects this difference: the 2005 survey asked about funding for "direct project costs" where the 1994 survey specified funding for "hardware and materials." [1]) Indeed, many 2005 respondents checked "Other" and commented that their design projects did not require funding.

Continuing the funding theme, Figure 18 depicts the average level of financial support per project from industrial sponsors. Results are relatively constant across the two surveys, with many projects receiving less than $500 from the sponsoring company. Nearly a quarter of 2005 respondents selected "Variable" (which was not an option on the 1994 survey) reinforcing earlier responses that suggest a wide range of funding even within a single program. For those who received $5,000 or more, the 2005 data were divided into several categories, not labeled on the graph due to their small percentages. In the largest of these, 5% of respondents answered that at least one of their projects received $5,000–$10,000; about 2% received more than $40,000. Comments received from the 2005 survey were similar to earlier questions on funding, in that many programs, if accepting funding at all, had no set standard and had sponsorship levels largely dependent on the participating company.

A comment from the audience at the 2007 Capstone Conference suggested correlating average direct cost per project with average industrial support per project; these results are shown in Figure 19. On average the data show a correlation between higher direct cost and higher industrial support and imply that variable industrial support was linked with a wide range of direct project costs. In some cases, the direct costs exceeded the industrial costs; comments written in suggested the additional cost was usually covered by the institution. In other cases, perhaps more advantageous for the institution, the level of industrial support exceeded the direct costs. Of additional interest

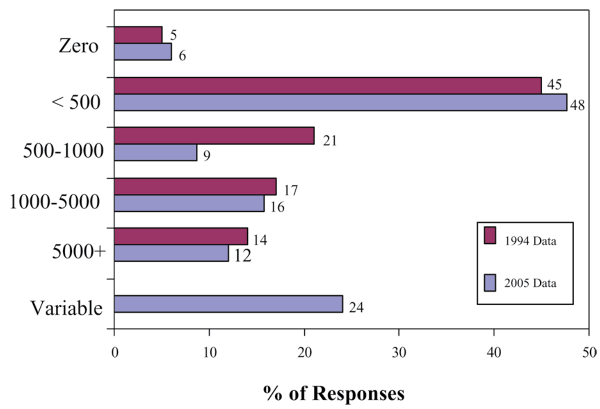


Figure 18: Amount of Industrial Support ($).

is the causal relationship between industrial support and direct cost: do higher levels of industrial support enable more expensive projects or do more expensive projects require higher levels of industrial support? The data in Figure 19 do not address the issue, but the question merits further study through targeted follow-up surveys.

A final question on capstone project funding asked if funds were offered in the form of gifts, grants or return for expenses. The responses, detailed in Table 6, show that about half of respondents received funds as gifts, while grants and return for expenses provided funding for a quarter to a third of respondents. Although respondents were allowed to select more than one of these answers, most chose only one, indicating a notable consistency in the form of funding. Data from a related question about funding destination suggest that in general these funds either went to the project directly or to the institution.

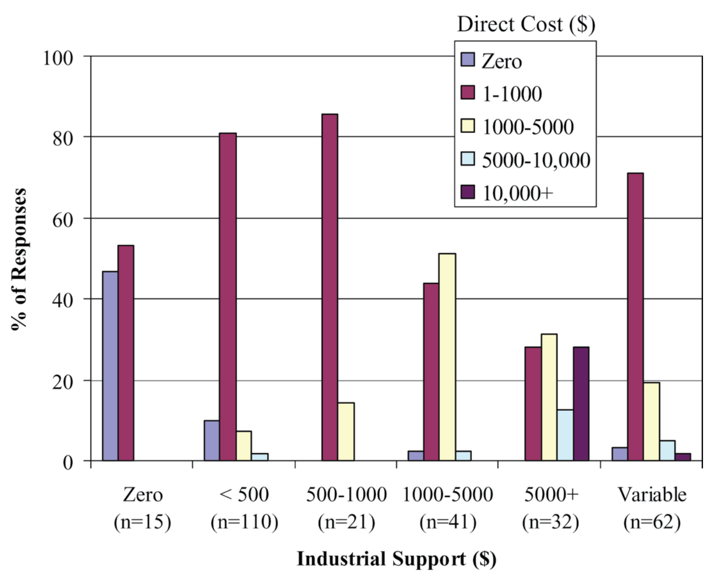


Figure 19: Industrial Project Support and Direct Project Cost.

Form of Funding	% Responses (n=236)
Grants	28
Gifts	52
Return for Expenses	32
Other	8

Table 6: Form of Funding.

E) Industry Sponsors

One question specifically for programs with industry sponsorship focused on the location of these sponsors, with results shown in Figure 20. Respondents were given the choice of "Locally" (within 20 miles), "Regionally" (20–100 miles), or "Nationally" (more than 100 miles). Local sponsors remained the most prevalent, with the 1994 data suggesting that these sponsors provided a convenient and ultimately more satisfying design experience due to ease of contact [3]. National sponsorships increased in frequency between the two surveys, however; almost half of 2005 respondents involved sponsors more than 100 miles away from their institution.

Figures 21 and 22 show the sponsor location data from the 2005 survey correlated with capstone program age and department. Local and regional sponsors were strong for programs of all ages. National sponsors were less likely for younger programs, but there is no noticeable pattern with age. Regarding department, CE respondents had mostly local and regional projects, and all of the IE respondents had at least one local project. The highest occurrences of national projects were in ME and Other departments. In all cases, the percentages in a given group sum to far more than 100%, meaning that most programs had projects from a mix of sponsor locations.

Respondents that had some projects sponsored by industry were also asked about the amount of contact between project teams and their sponsors; the results are presented in Figure 23. In both the 1994 and 2005 data, weekly interaction was the most frequent response by at least a small margin; in fact, the usual level of contact remained divided between weekly, monthly and beginning and final meetings. In both surveys, the constant level of "Other" responses and the

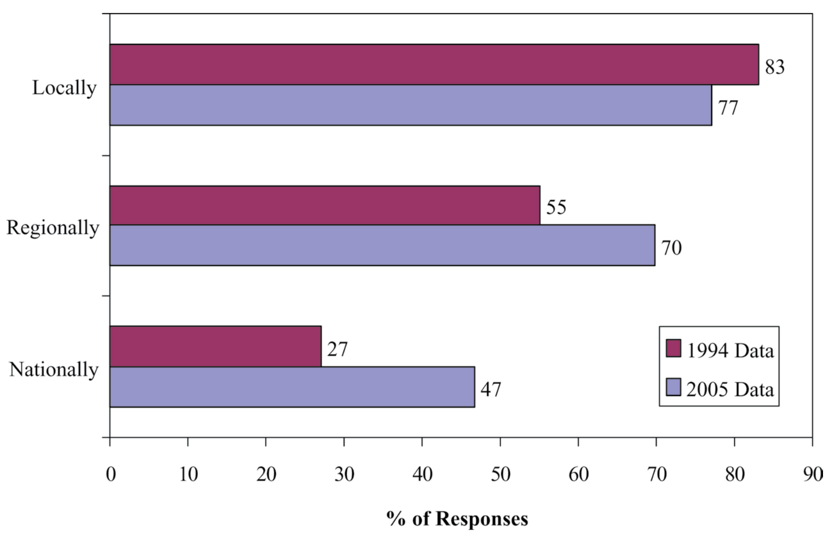


Figure 20: Location of Project Sponsors.

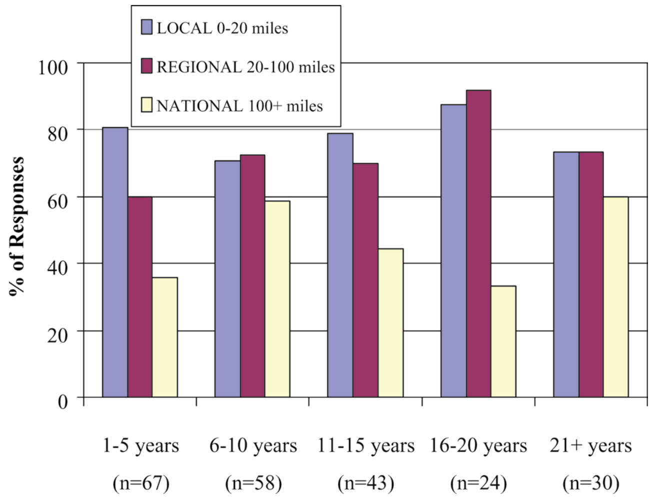


Figure 21: Sponsor Location and Capstone Age.

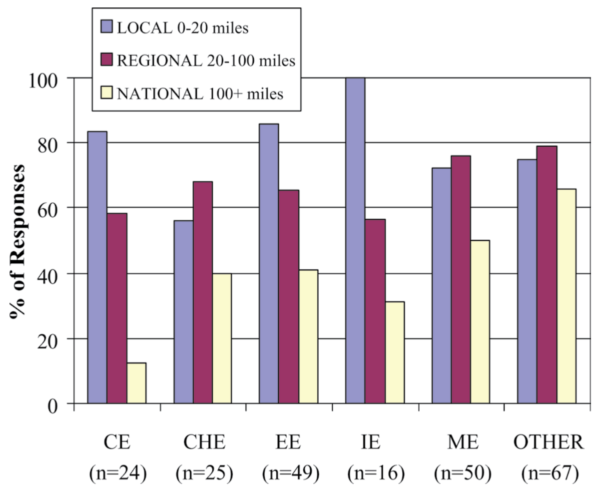


Figure 22: Sponsor Location and Department.

number of respondents who checked multiple boxes suggest that many respondents had different levels of contact for different projects. The comments from 2005 supported this conclusion: many wrote that the amount of contact depended on the client and the demands of the project. Several noted that beginning, interim, and final meetings were common, and a small percentage (1.5%) of 2005 respondents wrote that some teams met with sponsors more often than once a week.

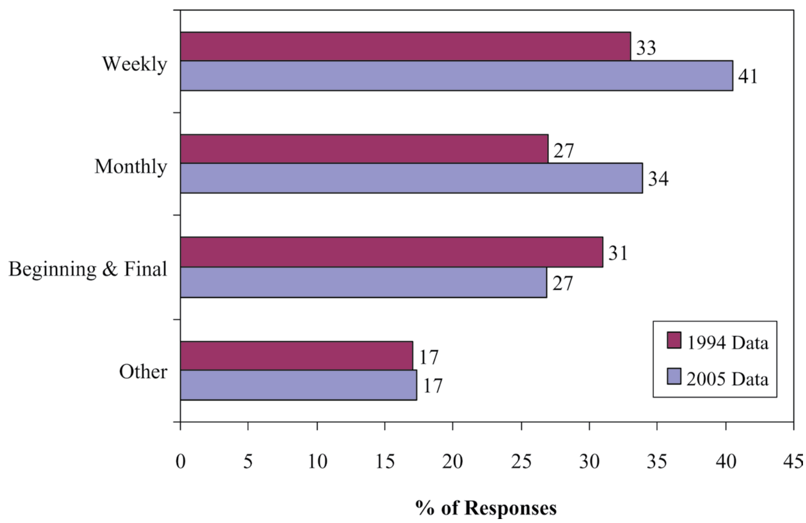


Figure 23: Contact with Sponsor.

Number of Trips	% Responses (n=221)
0	19
1	12
2	28
3-5	28
6-10	9
11+	5

Table 7: Typical Number of Trips to Sponsor.

The 2005 survey also asked respondents the typical number of trips students make to their sponsors; results are shown in Table 7. A strong majority visited their sponsor at least once but of those about half visited only once or twice while the rest traveled from a few to 11 or more times; many comments noted weekly visits. These results mean more given the range of sponsor location discussed above. Of the complete 235 respondents who noted having external sponsors in 2005, 77% had at least some local sponsorship (within twenty miles) and 17% had entirely local sponsorship; on the other hand, 47% involved at least some sponsors located over one hundred miles from the institution.

Figure 24 shows the results of a question regarding ownership of intellectual property. While sponsor ownership was the most frequent in the 1994 data, the number of sponsors possessing at least part of the intellectual property increased still further from 40% to 64% of respondents in 2005

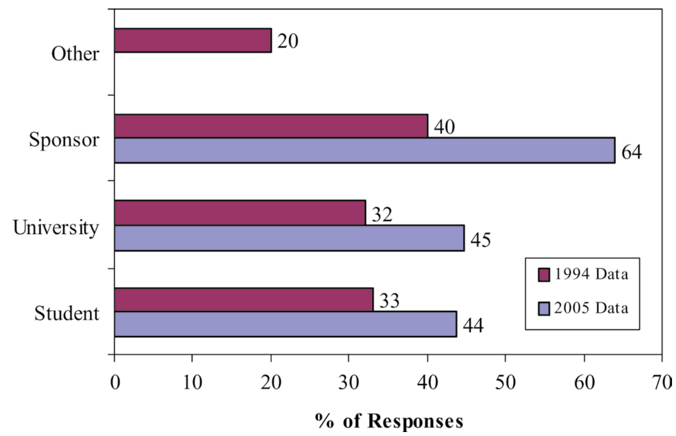


Figure 24: Intellectual Property Ownership.

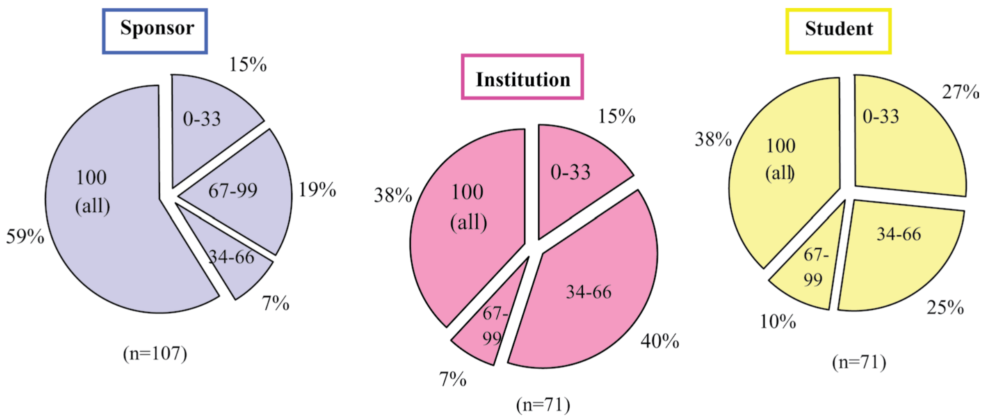


Figure 25: Percentage Breakdown of Intellectual Property Ownership.

(n = 217). Interestingly, ownership by both institutions and students remained fairly constant, and each was about equally likely to have some portion of intellectual control. Comments from the 1994 survey, which allowed respondents to check “Other,” found that many had worked out a different type of arrangement for intellectual property, or had no arrangement at all [3]. Comments from both surveys suggested there was great variation but that the level of sponsorship was also a factor.

Both the 1994 and 2005 data sum to more than 100%, suggesting that IP rights may often have been shared. This possibility was examined further in another 2005 survey question, which asked respondents to note the percentage of ownership granted to each entity. The results of this breakdown are indicated in Figure 25; the numbers inside the pie chart represent the range of percent ownership by a given entity and the numbers outside the pie chart reflect the percent of respondents who reported values in this range. As is clear in the sponsor chart, sponsors were distinctly more likely to own all of the intellectual property if they owned any. Institutions and students appear to have had a wider range of partial ownership, with full ownership going to either entity only 38% of the time. Otherwise, the respondents granted varying degrees of ownership, most often one to two thirds of the intellectual rights, to students and institutions.

CONCLUSIONS

This work discusses responses from a survey of engineering capstone design courses nationwide conducted in 2005. We implemented the survey online, solicited responses via email, and received a response rate of 66% among institutions and 26% among programs, for a total of 444 programs from 232 institutions. As a successor to a 1994 survey of capstone courses [1], the recent survey reprised the questions of its predecessor in addition to some new questions. Highlights of the results were presented in the opening keynote session of the 2007 National Capstone Design Course Conference. This paper directly parallels the keynote talk and draws heavily on previous publications [4, 5] of the results.

The data were grouped in five main categories: respondent profile, course/project logistics, faculty involvement, funding details, and industry sponsorship. The outstanding results from the 2005 data (in comparison, where feasible, with the 1994 data) are reviewed below, with more details available in the body of the paper.

- *Respondents:* The survey respondents represented a fairly even distribution across engineering departments; half of the capstone programs represented were less than ten years old in 2005.
- *Course/Project Logistics:* The 2005 responses on course structure suggest that a one-to-two semester course with simultaneous class and project components remained popular, while course content showed a greater breadth and a leaning towards professional skills. In the project area, most schools still assigned one team per project, with an increased tendency toward 4–6 students per team and 2–5 projects per course cycle. Departmental teams were the norm, with interdepartmental teams an increased and sizable minority. External project sourcing, either through industry or design competitions, increased in frequency and was the most common approach. Respondents reported wide variation in types/frequency of student presentations and strategies for determining student grades, but most held students at least partially responsible for finding time to meet and work.
- *Faculty Involvement:* Programs tended to involve either most or very few faculty in the course in general, and few in formal instruction, with a fairly consistent majority maintaining a

student-to-faculty ratio in the 1–5 (to 1) range. Average faculty involvement varied little across age of capstone program and slightly more across department. The majority of capstone faculty received teaching credit for their involvement.

- *Funding Details:* Direct costs were most often less than $1000 per project, and tended to cover supplies and hardware, among other things; no large variation in direct cost was evident across either capstone age or department. Direct project costs were most often covered by the institution, though industry sponsorships grew more common. Amount of funding from industry ranged from $0 to $40,000 with the majority of respondents receiving less than $500; these funds were most often gifts, return for expenses, or grants. In general, high direct project costs were correlated with high levels of industrial support.
- *Industry Sponsors:* Location of industry sponsors ranged from local to national. National sponsors were less likely for younger capstone programs but more likely for ME and Other departments, whereas CE respondents involved more local and regional sponsors. Students had increased contact with their sponsors and the majority visited the sponsor at least twice. Sponsors were the most likely owner of some or all of the intellectual property rights.

This work was motivated by a desire to better understand engineering capstone courses and practices employed by capstone educators on a national scale. The 2005 survey results serve as (1) a compilation of logistical and implementation information about recent engineering capstone education programs and (2) a springboard for future research on the subject to enrich and advance capstone education in engineering. Highlights of the results were presented at the 2007 Capstone Conference to provide context for the conference sessions and prompt further discussion and study.

The combination of the trends reported here and the difficulty of characterization nationwide argue for a final conclusion: the importance of further research on practices, general and best, within capstone education. Indeed, capstone courses are a widespread component of engineering education that offer a positive learning opportunity for students: respondents in the 2005 survey reported an average faculty rating of 8.6 out of 10 and an average student rating of 8.5 out of 10 when asked how the educational value of their capstone course generally rated. Moreover, the prevalence of institutions with established means of assessing their capstone courses (90% of 2005 respondents reported having some method of determining capstone course success) suggests that faculty are well-versed in providing information about their courses. Suggested future research areas include follow-up surveys on targeted areas (such as project funding levels, IP ownership, adjunct vs. full-time faculty involvement, and course management strategies), longitudinal studies, correlation with assessment of outcomes, and expansion to a global perspective. Capstone courses merit further study to understand and realize their full potential.

ACKNOWLEDGEMENTS

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BIOGRAPHICAL SKETCH

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