# AC 2012-3779: NATIONAL TRENDS IN THE CIVIL ENGINEERING MAJOR DESIGN EXPERIENCE

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# National Trends in the Civil Engineering Major Design Experience

Civil Engineering Programs applying for ABET accreditation are required to describe their major design experience that prepares students for professional practice. What is a major design experience and how is student performance evaluated? This paper presents the results of a survey of Civil Engineering Departments across the U.S. to determine the type of major design experiences that exist. The survey identifies the common length of design experiences, types of projects, team or individual requirements, multidisciplinary characteristics, grading methodologies, and professional skills instruction provided during the design experience. The paper does not evaluate or assess the effectiveness of any one method but rather attempts to provide a comprehensive look at the variations and possibilities within a major design experience.

## Introduction

The culminating major design experience has been an integral part of selected engineering curricula for decades. However, with the introduction of ABET's EC 2000 it became a requirement for all engineering programs for accreditation. ABET's current language for the 2011-2012 accreditation cycle reads, "Students must be prepared for engineering practice through a curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints." [1] ABET does not define the required course content or length, the types of projects that are considered a culminating design experience, requirements related to individual and/or team projects, or which skills to assess. It is reasonable, then, to ask what constitutes an appropriate major design experience. There are a significant number of papers in the literature by individual departments describing their approach, but few that provide a compendium of common themes and methodologies.

An exception is the 2005 national survey of all engineering departments conducted by Howe and Wilbarger.[2] Their study was a follow-up to a 1994 survey conducted by Todd et al.[3] The original 1994 study surveyed 1021 departments with 35 percent responding. The 2005 study surveyed 1724 departments with a 25 percent response rate. Only 28 percent of the responding departments completed both surveys, with over 45 percent of those responding to the 2005 survey indicating their major design experience was less than 10 years old; most likely a result of the EC 2000 major design experience requirement. An additional study reported by McKenzie et al in 2004 surveyed 274 deans with 119 institutions, representing a total of 298 departments.[4] This study provided a general look at major design experiences with a focus on assessment of capstone design.

For any department looking to create or revise a major design experience, determining the scope of projects, assessment methods, unit requirement, team size requirements, etc. can be overwhelming. What is appropriate for one school may not be appropriate for others. To provide a tool to assist Civil Engineering departments as they develop their experiences, this paper presents the results of a national survey regarding the capstone design in Civil Engineering. The paper does not evaluate or assess the effectiveness of any one method but rather attempts to provide a comprehensive look at the variations and possibilities within a major design experience. Where possible, comparisons to the 1994, 2004 and 2005 surveys are offered.

**Survey Methodology**

This survey was conducted electronically using the web-based tool Survey Monkey®. The survey was sent to the Department Heads' email list through the American Society of Civil Engineers, ASCE, Educational Activities Committee (EDAC). This list includes departments with Civil, Environmental, Construction and/or Architectural Engineering programs. Over 200 departments are on the listserve. Recipients were given three weeks to reply to the email request. Reminder emails were sent one week and two days prior to the survey's close.

Responses were recorded for 101 schools, resulting in a response rate of less than fifty percent. The survey asked a variety of questions regarding the school type, the nature of the capstone experience, team size and make up, project details, project mentoring, industry involvement, any material taught during the course, the topics assessed, and how assessment was conducted. The majority of questions required respondents to choose from a provided list of answers to allow for tabulation of the results. Questions also allowed respondents to answer "Other" and provide details. If multiple "Other" responses addressed the same topic, a new category was included in the tabulation of results. Respondents were provided an option at the end of the survey to email a course description or syllabus.

**Respondent Profile**

Of the 101 schools that responded to the survey, 25 are private institutions with the remainder being public. As shown in Figure 1, 62 (81.6 percent) of the 76 public schools are Ph.D. granting institutions, nine (11.8 percent) offer both Master's and Bachelor's, and five, (6.6 percent), are undergraduate-only institutions. Among the private institutions, 13 (52 percent) are Ph.D. granting institutions, eight (32 percent) offer both Master's and Bachelor's, and four (16 percent) are undergraduate-only institutions.

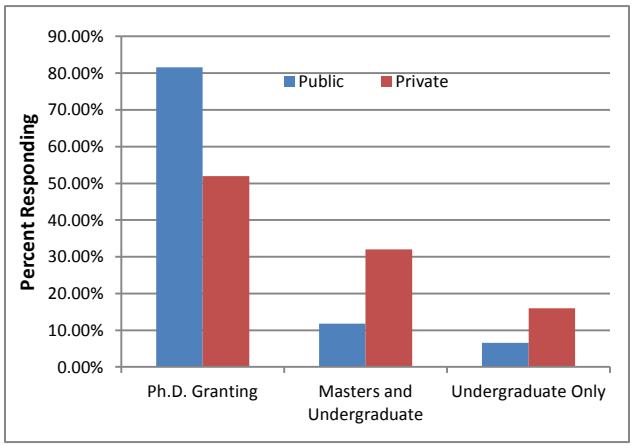


Figure 1: Demographics of Responding Schools

When asked if they currently have a major design experience, 99 out of the 101 responding departments answered yes. Of the two departments who responded no, one plans to implement a capstone course within one to two years. The other has no plans to implement.

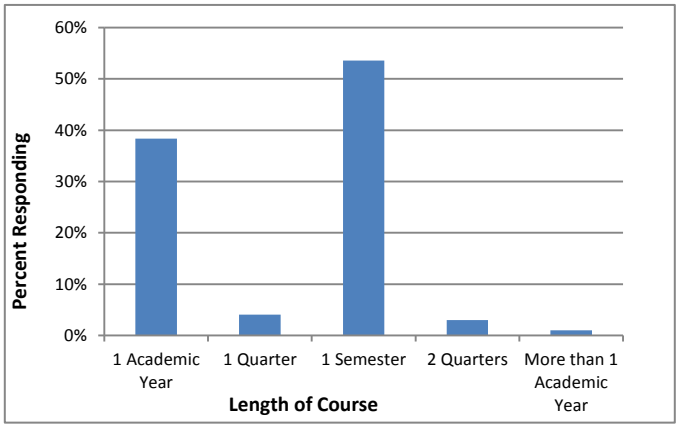


Figure 2: Percent of programs responding with the shown course lengths.

## Course Information

Course Length and Expected Student Effort:

Over 50 percent of respondents indicated their major design expeience is a semster long project, with 38 percent reporting year long projects. As shown in Figure 2, less than five percent of courses last one or two quarters. Only one school indicated their program was over a year long.

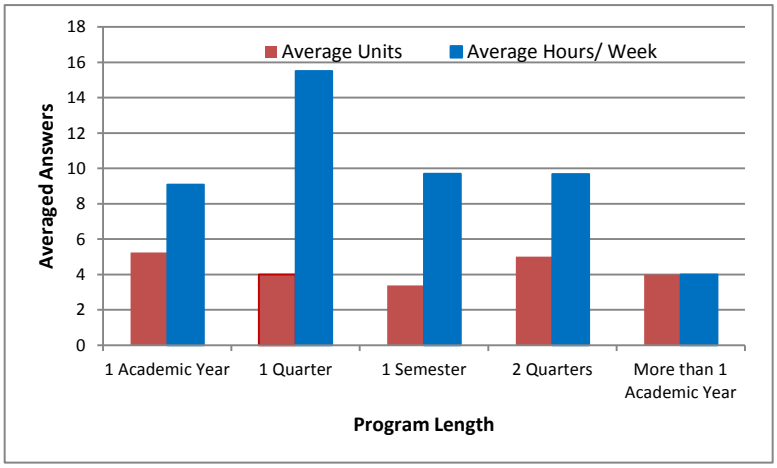


Figure 3: Average Assigned Units and Expected Weekly Work Hours by Program Length

Interestingly, the 2004 survey found 57 percent of programs were a year long and 31 percent a semester long, while the 2005 survey found the percentages were similar with both semester and year long projects between 42 percent and 47 percent, respectively. Perhaps this trend toward semester-long courses instead of year-long is a function of the increasing program content requirements with decreasing available credit hours.

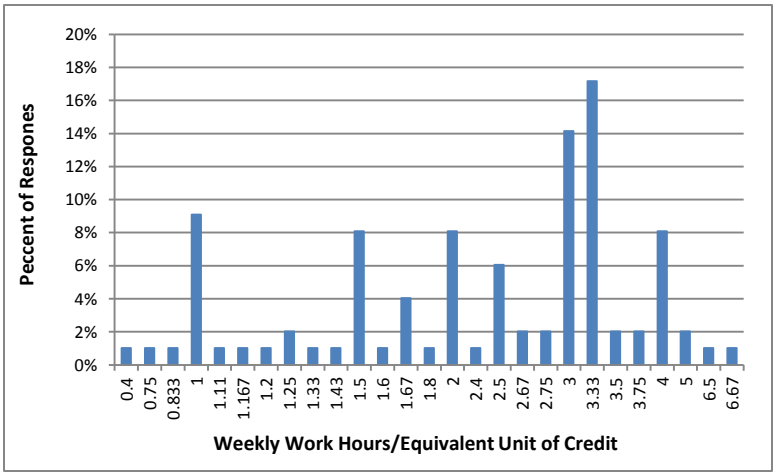


Figure 4: Expected weekly hours of work per each equivalent semester unit

Programs were also asked to indicate the number of total units awarded to the major design experiences along with the expected hours worked per week. It was interesting to note, the quarter long projects had a significantly higher expected average hours worked per week versus units earned than other

project lengths as shown in Figure 3. Projects lasting one semester, one year or two quarters all had similar time expectations of nine to ten hours per week. The average units awarded for capstone courses ranged from three to five depending on the total project length.

To better understand how the weekly time expectations for units awarded compared over the length of a project, the equivalent average semester units were determined. For example, units awarded to a year long project were divided by two and units awarded to a quarter long project were multiplied by 1.5 to find the equivalent units for one semester. The weekly expected hours were then divided by the corresponding average equivalent semester units. Figure 4 indicates the majority, 31 percent, of departments expect an average of 3 to 3.33 hours of work each week for every unit of credit awarded. Four hours, two hours and one and a half hours of work per week each received 8 percent of the responses and one hour of work per week received 9 percent.

Team Size and Selection:

Respondents were asked to indicate whether students worked as individuals or in teams and the size of the teams. Totals for this question exceed 100 percent as responders were free to choose multiple answers. Figure 5 shows that four to five team members were the most common. In fact, 45 percent of departments indicated four to five members as the only option for their teams sizes. Fourteen percent indicated teams could only be six members or larger with only three percent of departments indicating teams of 2-3 or smaller. Only six schools (6 percent) of respondents indicated students are allowed to work as individuals. Of these, one school indicated students have separate individual and team projects. The remaining five schools indicated individual projects were an option but not required. This is similar to the 2004 study, which found 10 percent of students work as individuals; it is significantly less than the 1994 and 2005 studies, which reported 32 percent and 18 percent respectively. The rapid decline in individual projects may be explained, at least partially, by the ABET EC 2000 requirement for a "multidisciplinary" experience.

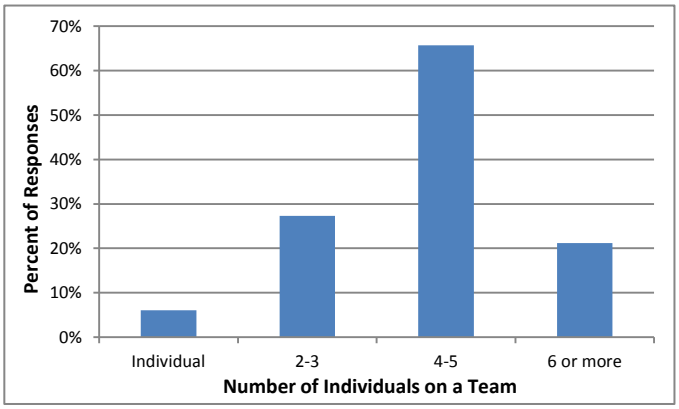

Figure 5: Number of members on a design team.

Methods for assigning teams varied greatly as shown in Figure 6. The most common response had faculty assigning the teams based on students' preferred discipline, followed closely by students self-selecting teams and faculty assigning teams using a combination of student team preferences and chosen dispcipline. Two schools indicated the faculty assign team leaders and those leaders chose the teams. This was added to Figure 6. One school indicated considering a student's maturity and leadership skills to form teams, while a handful used a combination of the provided answers.

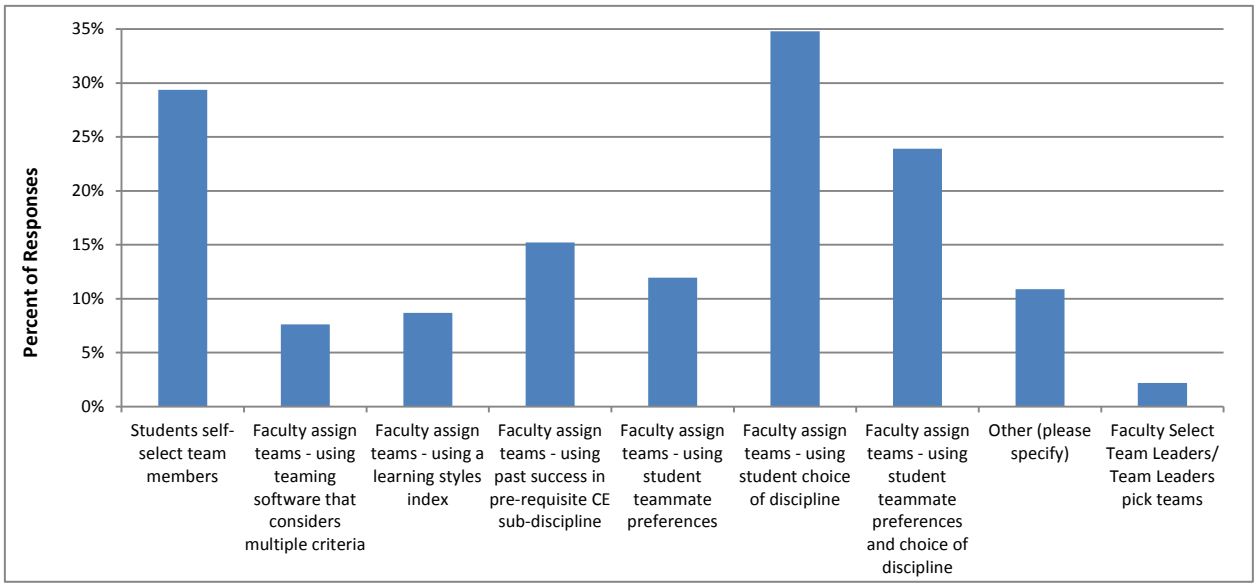


Figure 6: How student teams are assigned, displayed by percent of respondents

## Project Types:

Overwhelmingly departments indicated using real world projects as a source for project ideas (Figure 7), with 78 percent of responding programs with capstone courses indicating using 'current' real world projects (under construction) and 83 percent indicating using 'future' real world projects. One respondent reported using past real world projects. Only 17 percent of departments have projects based on research with 16 percent of projects resulting in a physical product.

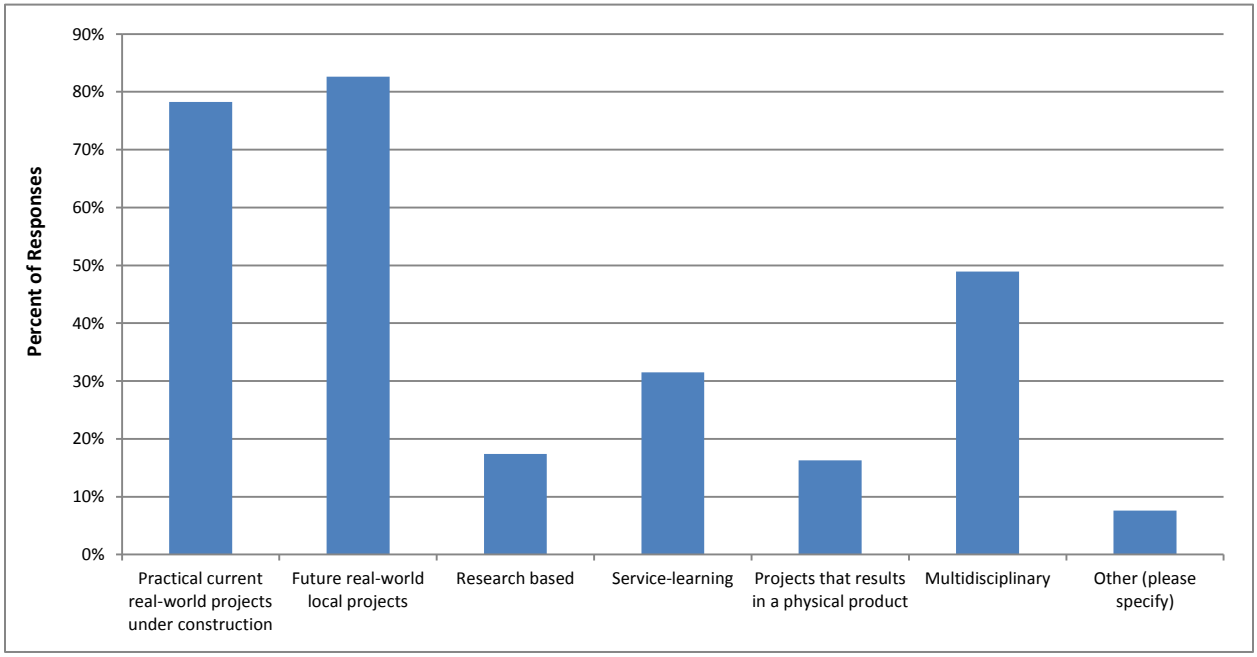


Figure 7: Types of Projects

A total of 49 percent of respondents reported the projects were multidisciplinary. This closely corresponds to the 2004 survey that found 47 percent of projects were multidisciplinary. Within these schools, 64 percent require each student to be a content expert in one area and partner with other content experts. These schools require an average of 2.66 disciplines for a multidisciplinary experience. The remaining 36 percent of departments with multidisciplinary projects require students to demonstrate expertise in more than one area. However, these schools also indicated teams should have an average of 3.5 other disciplines on each team. The majority of departments defined multidisciplinary as made up of the different sub-disciplines within civil engineering. Disciplines outside of civil engineering such as business, other engineering fields, environmental sciences, and humanities, were required by 24 percent of departments with multidisciplinary projects.

Among responder comments, it was clear that project types also vary between individual projects for each team, or a single project on which the entire class works - with each team working on a different aspect of the project. One department described the class project as, "*Teams design a large land development that is subdivided into pieces and each team is given different areas and design constraints*."

Project Idea Development:

Departments were asked to identify all sources for project ideas. Industry partners were noted by 80 percent of departments as a source of ideas. Faculty interests and government agencies were both mentioned by approximately 55 percent of schools as shown in Figure 8. Among the written responses in the "Other" category; private citizens, projects from student design competitions, university competitions, and community projects were identified along with government agencies and industry consultants. A unique response from one department noted, "*Projects come from recent industry developments presented at conferences or symposia*".

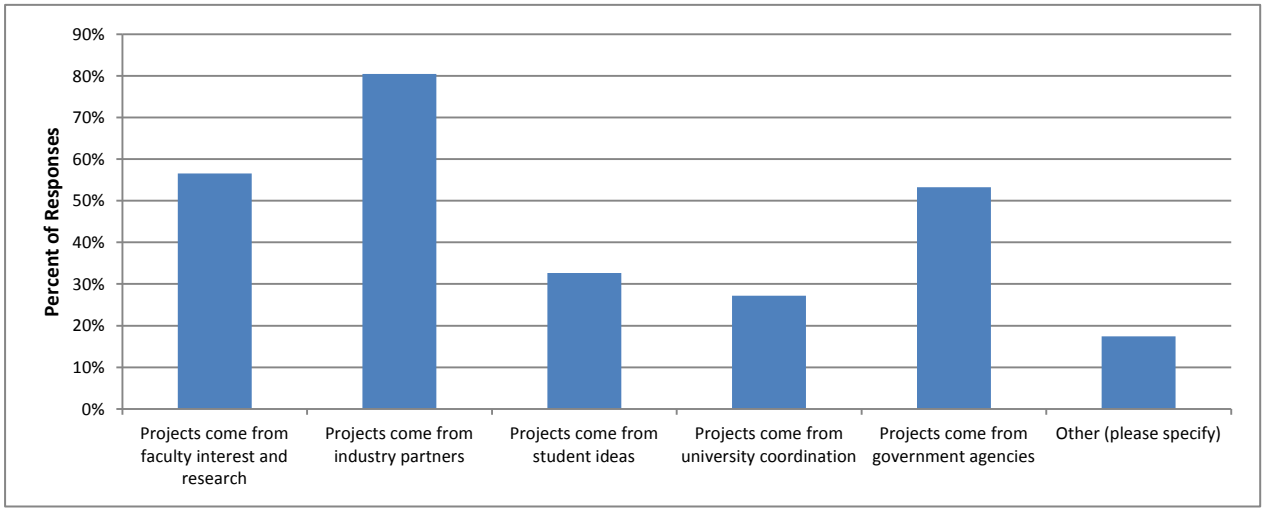


Figure 8: Sources for project ideas

Responders were also asked to indicate the typical percent of projects that come from each source. Figure 9 illustrates the majority of projects do come from industry and the smallest percents coming from student ideas, university coordination and faculty research. The four "Other" responses that indicate 50 percent or more projects come from "Other" were all identified as local industry or local consultants by the respondants.

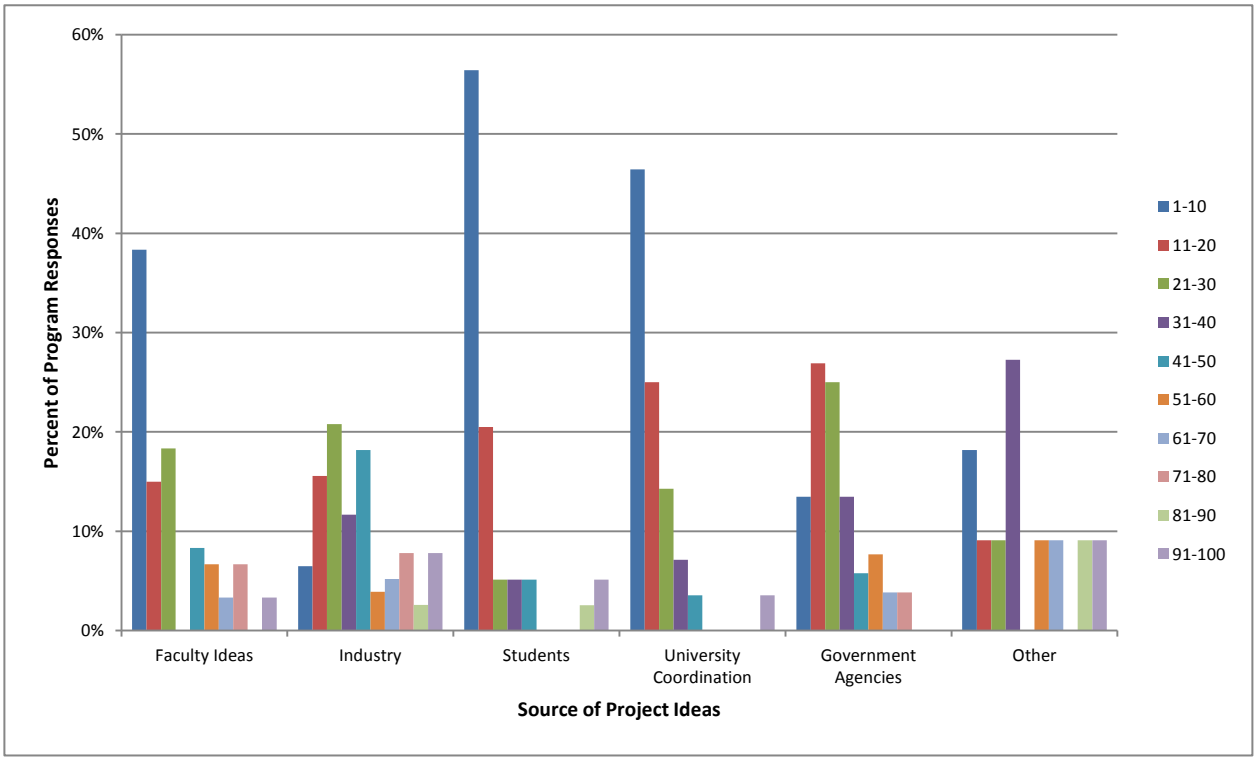


Figure 9: Percent of project ideas stemming from indicated source and grouped by percent of projects

**Student Advising/Mentoring**

When asked who primarily provided student mentoring on their major design experience, 38 percent of departments indicated both a faculty and industry mentor. About 26 percent reported a course manager or director provided the majority of the mentoring. The limited "Other" responses included "it depends on the project" and "course director, faculty and industry mentor". Figure 10 shows the complete breakdown of responses.

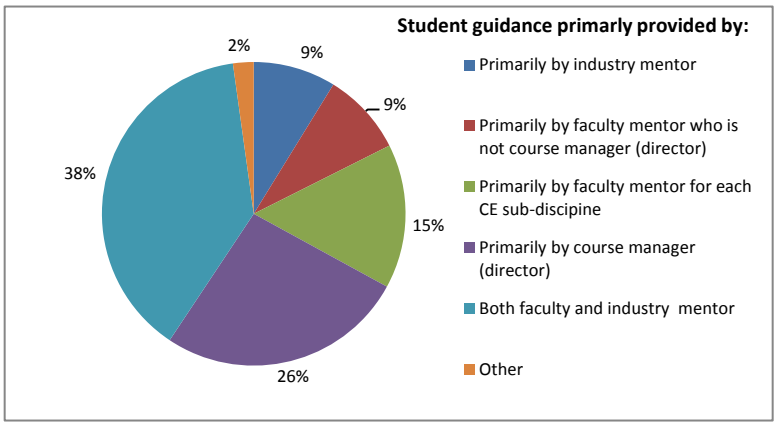


Figure 10: Primary advisor or mentor of students

**Course Content and Assessment**

Eighty-five departments are using the major design experience as an opportunity to teach a wide variety of topics, including the 'soft skills' required by ABET. Over 80 percent of the 85 departments report teaching project management, teaming skills, oral communication, and technical writing or written communication. It should be noted, however, that one school reported their ABET evaluator gave them a warning for including the soft skills in their major design experience and have since removed these from their capstone course. Figure 11 provides the proportion of the 85 departments who reported teaching the given topics. Design process and scheduling are also taught by the majority of schools. Listed after "Other" are the four most commonly noted other topics: professional practice, ethics, safety, and licensure or life-long learning. These areas, among others, are described in ASCE's *Civil Engineering Body of Knowledge for the 21st Century* (2nd Ed.) as topics important to future civil engineers.[5]

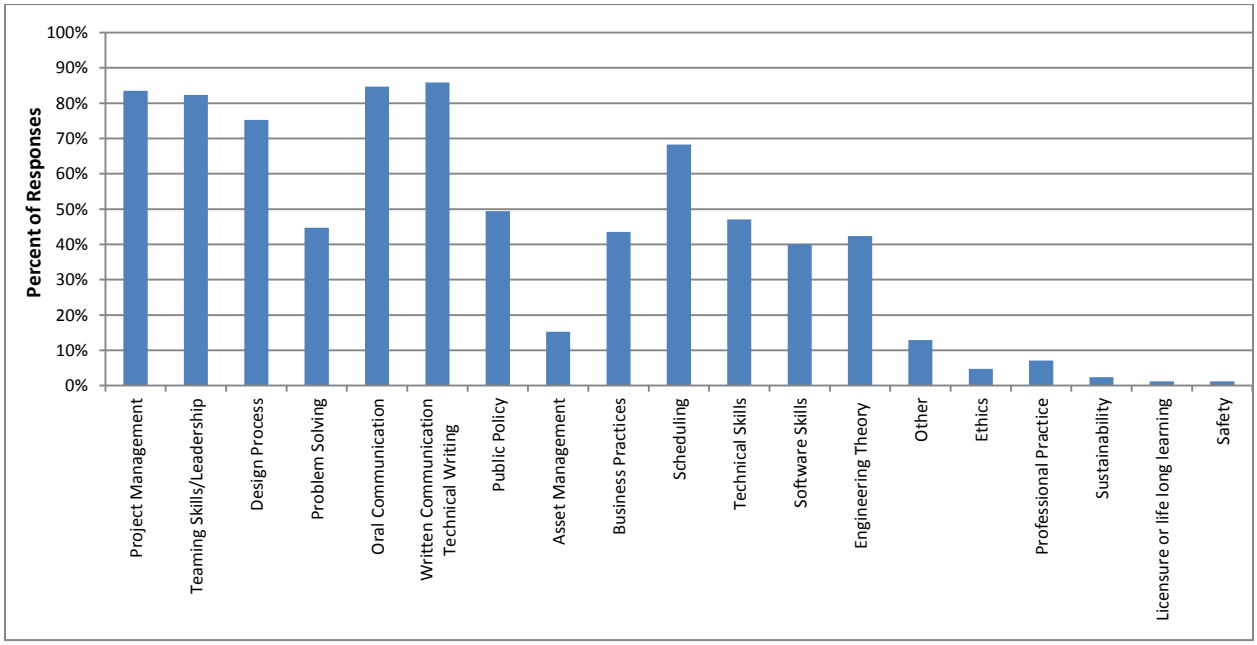


Figure 11: Topic areas taught by the 85 departments that report teaching during the major design experience.

Not all the topics taught by the departments are assessed. Figure 12 compares the number of schools providing instruction in the major design experience in each topic area versus the number of schools that assess those same topic areas as part of the major design experience grade. Interestingly, 16.5 percent of the departments that indicated they provide instruction also indicated they do not assess those same skills as part of the major design experience. One department reported assessing the design process, oral communication and written communication but did not report providing any instruction as part of the major design experience. This resulted in 72 schools that reported assessing on one or more of the suggested topic areas. Because the count of departments responding was different for teaching versus assessing, Figure 12 is reported as a count of respondents instead of percent.

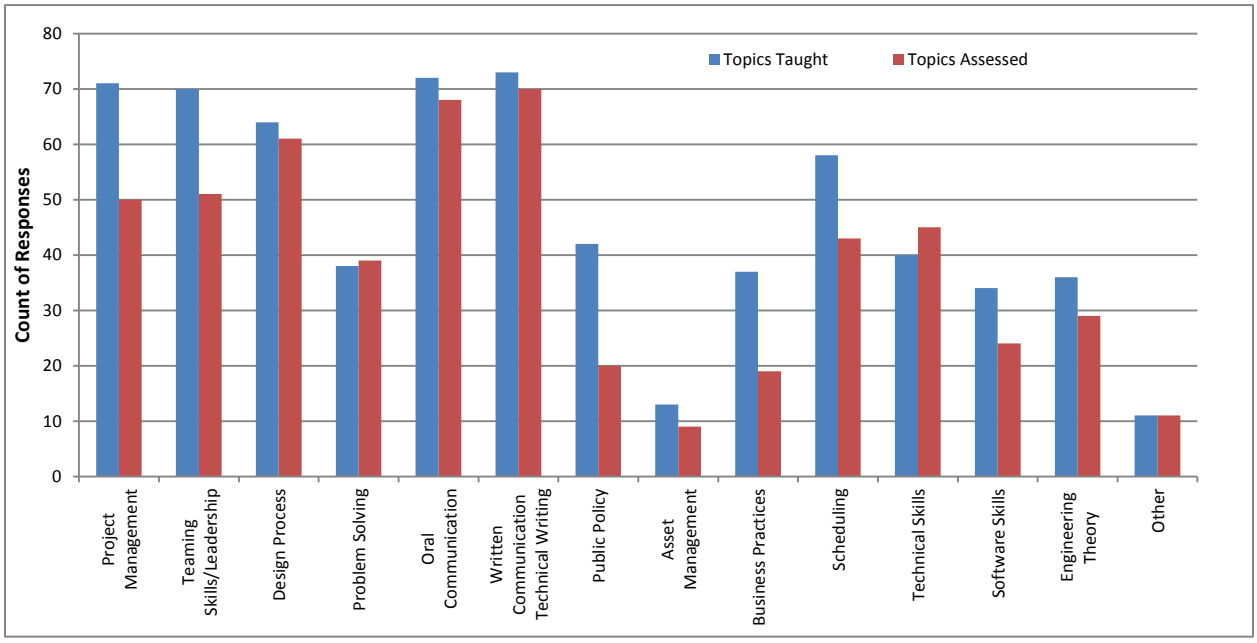


Figure 12: Topic areas taught versus topic areas assessed, 85 schools responded teaching one or more topics while 72 schools responded assessing one or more topic.

Project management, teaming skills, business skills, public policy, and scheduling have the largest discrepancy between the number of schools that teach these topics and those that assess them. Oral and written communication are assessed by the majority of the 72 responding departments with 68 and 70 departments (94 percent and 97 percent, respectively) indicating assessment of these areas. The 2004 survey also found effective communication as the most assessed skill with 95 percent of departments reporting its assessment.

When determining the actual grade for the major design experience, the departments indicate using peer assessment, industry evaluation, and faculty evaluation. Departments also indicated that grading was predominantly done by each group using rubrics. To explore the possible relationship between the person/group providing student mentoring and the person/group performing student assessment, responses were analyzed in Figure 13. The data indicate that faculty evaluation is the predominant source of assessment with 28 schools specifying 80 percent or more of the grade is provided by faculty. Peer assessment is the least used form of assessment. However, 37 schools do indicate that 10 percent or less of the grade comes from peer assessment, with eight schools assigning 30 - 60 percent of the grade by peer assessment and one providing 80 percent. There is an observable higher incidence of industry evaluation in those programs that have combined mentoring from industry and faculty, or those that have only industry mentors. When faculty provide the mentoring based on the project or the civil engineering sub-discipline, the least amount of industry evaluation occurs. Overall, 20 programs indicate that 30 - 60 percent of the project grade is determined by industry evaluators.

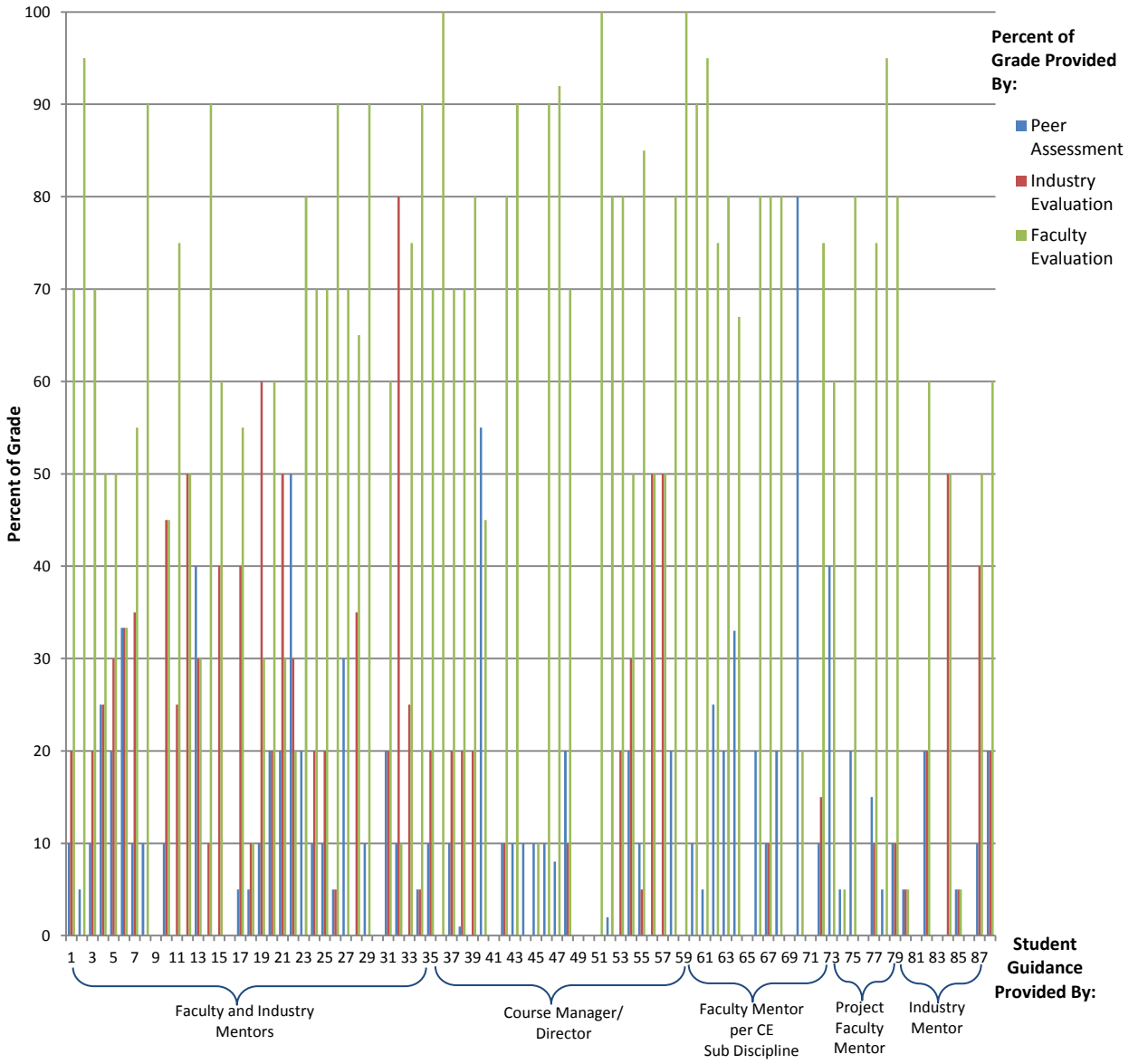


Figure 13: 88 total responses separate by percent of grade provided by peer assessment, faculty evaluation and industry evaluation for each department. Responses organized by who provides student guidance.

To determine what grade to assign to each member of a team, 73.9 percent of departments indicate grading students as individuals. Overwhelming, departments reported that the project and project report is graded as a whole and then peer evaluations affect the percentage of the individual grade. Faculty evaluations of individual student performance on the project, along with individual assignments and presentations are also used to assess individual grades. Within the remaining 26.1 percent, departments indicated grades are assigned to the entire team. However, 39 percent of these departments clarified that a percentage of an individual's grade is based on some form of individual work including presentations, peer reviews, exams and individual assignments. As this clarification describes a grading method similar to those described by departments assigning individual grades, it may be more accurate to include these

departments with those that grade students individually. This would result in 84 percent of departments grading students as individuals.

In terms of assessing students as teams or individuals, one department noted: "*Each student must keep an engineer's log book of their work. The log book counts 25 percent of the final grade. Also, their contribution to each team effort, such as the final report and final oral presentation, is assessed individually. Also, teams must do some fabrication/testing of their design and this counts 15 percent of their final grade. Exams on lecture materials, which count 15 percent of final grade, are also assessed individually."* A work log was mentioned by three departments.

## Summary of Major Findings

The following table provides a synopsis of the survey results. The maximum and minimum responses along with the two most common responses are summarized for each survey question.

Table 1: Summary of survey results indicating common trends

| Design Experience Feature | Range of Responses (101 programs reporting) (values in **BOLD** indicate number of programs reporting the result) | | | |
|---|---|---|---|---|
| | **Min** | **Max** | **Most Common** | **Next Common** |
| **Project Length** | 1 Quarter | > 1 Year | 1 Semester | 1 Year |
| | **1** | **4** | **53** | **38** |
| **Academic Credits** | 2 credits | 10 credits | 3 credits | 4 credits |
| | **3** | **2** | **41** | **28** |
| **Expected Work (Hours) Outside Class** | 2 hours/week | 26 hours/week | 10 hours/week | 6 hours/week |
| | **1** | **1** | **30** | **14** |
| **Expected Outside Work (Hours) per Academic Credit** | 0.40 hr/credit | 6.67 hr/credit | 3.33 hr/credit | 3.00 hr/credit |
| | **1** | **1** | **17** | **14** |
| **Projects Assigned by…** | Students (all variations) | Faculty (all variations) | Faculty (various projects) | Faculty (one project for all) |
| | **35** | **66** | **37** | **29** |
| **Source for Project Ideas** | University Coordination | Industry | Industry | Faculty |
| | 5.84% of ideas | 34.83% of ideas | 34.83% of ideas | 17.96% of ideas |
| | **28** | **77** | **77** | **60** |
| **Project Type** | Physical Product | Future real-world | Future real-world | Current real-world |
| | **15** | **76** | **76** | **72** |
| **Number of disciplines in projects** | 1 discipline | 6 disciplines | 2 disciplines | 4 disciplines |
| | **3** | **1** | **18** | **14** |
| **Student Team Size** | Individual (1) | 6 or more | 4 to 5 students | 2 to 3 students |
| | **6** | **21** | **65** | **27** |
| **Student Team Selection** | Faculty select leaders; leaders pick | Faculty assign; student preferred discipline | Faculty assign; student preferred discipline | Students self-select |
| | **2** | **32** | **32** | **27** |
| | **8** | **36** | **36** | **25** |

| Design Experience Feature | Range of Responses (101 programs reporting) (values in **BOLD** indicate number of programs reporting the result) | | | |
|---|---|---|---|---|
| | **Min** | **Max** | **Most Common** | **Next Common** |
| **Primary Student Guidance Provided by…** | Industry Mentor | Faculty and Industry Mentor | Faculty and Industry Mentor | Course Manager / Director |
| | **8** | **36** | **36** | **25** |
| **Instruction Provided in Specific Topics** | Licensure / Lifelong Learning | Written Communication / Technical Writing | Written Communication / Technical Writing | Oral Communication |
| | **1** | **73** | **73** | **72** |
| | | | Project Management | Teamwork / Leadership |
| | | | **71** | **70** |
| **Project Areas Assessed and Average Percent of Grade** | Asset Management | Written Communication: Final Report | Written Communication: Final Report | Oral Communication: Final Presentation |
| | 0.68% of grade | 14.1% of grade | 14.1%of grade | 9.88% of grade |
| | **4** | **70** | **70** | **58** |
| | | | | Design Process |
| | | | | 11.87% of grade |
| | | | | **57** |
| **Assessment Tools** | Industry Assessment without Rubric | Faculty Assessment with Rubric | Faculty Assessment with Rubric | Peer Assessment with Rubric |
| | **10** | **71** | **71** | **47** |
| | | | | Industry Assessment with Rubric |
| | | | | **45** |
| **Percent of Grade based on Assessment Tools** | Industry Evaluation | Faculty Evaluation | Faculty Evaluation | Peer Assessment |
| | 11.78% of Grade | 47.9% of Grade | 47.9% of Grade | 9.9% of Grade |
| | **40** | **72** | **72** | **49** |
| **Students Assessed as Teams or Individuals** | | | Individuals | Teams |
| | | | **58** | **22** |

## Conclusion

Although the major design experience is now a required culmination for an ABET accredited engineering curriculum, standards on what constitutes an appropriate experience have not been set. This paper describes the results of a national survey of current practices in civil engineering departments in regards to the major design experience. While variations existed, the survey identified predominant trends across the nation.

The most common form of the culminating design experience is a one-semester course counting for three academic credits. Students would be expected to work approximately 10 hours per week outside class or 3.33 hours per academic credit. Projects are assigned by the faculty, with most ideas stemming from industry input. The projects represent 'real-world' situations which could be designed and constructed in the future. Projects are multidisciplinary, featuring at least

two disciplines, where the sub-disciplines of civil engineering are most commonly considered as other areas. Students work in teams of 4 to 5, assigned by the faculty with student input regarding his/her preferred discipline. Student guidance is provided by both the faculty and an industry mentor. Students are also provided specific instruction in the areas of written and oral communication, project management, and teamwork/leadership skills. Final projects are assessed by the faculty, using a grading rubric, primarily on the quality of the written Final Report. Students are assigned an 'individual' grade based primarily on the faculty evaluation, which may be modified by results from a peer assessment.

After review of the data, the authors have determined modifications to the survey that would have improved this data; however, the survey was already long according to some respondents. These include:

- Report on each program within the department separately.
- Provide expected work hours per week to include "per person". It is possible some responses were per project.
- Provide a list of possible disciplines for multi-disciplinary projects to consolidate answers.
- Provide more direction on how team versus individual work is assessed.
- Add a question to determine if the department is ABET accredited.
- Add a question to determine when is their next ABET accreditation visit.
- Add an option to the survey to allow departments with different major design experiences for the sub-disciplines within their department to clarify the differences.
- Break number of individuals on a team into individual, 2-3, 3-4, 4-5, and greater than 6 since many programs will have multiple team sizes based simply on the number of students in the course at the time.
- Indicate the typical enrollment in the capstone course in a given semester/quarter.
- Add a question on why they are teaching (new) topics within the capstone course.
- Add a question on when they started their capstone course and why.

A continuous improvement process is a vital component of a program seeking to attain and maintain ABET accreditation. As part of this process, programs will typically assess their capstone courses to improve student learning related to the major design experience. The authors believe that the data and trends identified from this survey will provide guidance to programs seeking to make educated decisions on possible adjustments to their current major design effort. The current trends validated the practices at the authors' institutions.

Acknowledgements: The authors would like to thank the Civil Engineering Department Heads who took valuable time out of their schedules to thoughtfully complete the survey.

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