

Capstone Design Courses and Assessment: A National Study

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Abstract

ABET EC 2000 Criteria 3 and 4 specifically focus on student learning objectives and associated assessment and evaluation practices that are often integral to capstone design courses. This paper reports findings from a two-phase study conducted to better understand the nature and scope of assessment practices within capstone design courses across engineering disciplines, and in particular, the extent to which current practices align with ABET EC 2000 expectations. Phase 1 provides the findings from a nationwide survey of engineering disciplines in the U.S. with accredited engineering programs. One hundred nineteen of 274 institutions surveyed returned usable surveys for an institutional response rate of 43%. Faculty at these institutions were asked a variety of questions about the nature of the capstone experience, type of assessments employed, and the extent to which current practices align with ABET EC 2000 Criteria 3 and 4 expectations. Faculty members report that some ABET EC 2000 Criteria are currently not well assessed in capstone design courses and expressed interest in collaborating with colleagues across the country on capstone design assessment, development, and use. Phase 2 reports the findings from interviews and surveys of 98 faculty members identified from Phase 1. Faculty members were asked a variety of questions about classroom assessment practices in capstone design courses. Findings suggest uncertainty on the part of many faculty members concerning sound assessment practices, including writing objectives, using appropriate assessment strategies, sampling material appropriately, and controlling for mis-measurement of student achievement. Based on the findings a variety of recommendations are reported in this paper.

Introduction

The quality of teaching and learning in programs preparing undergraduate students for engineering practice is a focal point of national interest¹. Reasons for the concern include declining enrollment in undergraduate engineering programs and the need to increase and expand the professional competency of the engineering workforce. Engineering design, in particular, has received considerable scrutiny. Proposals to enhance engineering design education have included the development of design expectations across the curriculum, team-based learning activities, and assessments to gauge student attainment of outcomes^{2,3}.

One aspect of design education now receiving attention is the capstone design experience. Todd et al. in 1995 surveyed capstone engineering courses throughout North America to understand current practices in capstone education⁴. The study found that many engineering programs were using senior design/capstone-type courses to help prepare students for engineering practice, and a significant number of institutions engaged industrial clients to sponsor capstone projects. In addition, a number of schools were using undergraduate team based projects, with a few using inter-departmental undergraduate teams from different disciplines. They concluded that this faculty intensive investment was valuable in producing competent engineering graduates. The study did not investigate assessment practices within the capstone course.

Engineering Criteria now being implemented by the Accreditation Board for Engineering and Technology (ABET) mandate outcome based assessment of graduating engineers' abilities to apply technical and other professional skills to solve real-world engineering problems⁵. Engineering Criteria 3 and 4 of EC 2000 in particular, require integration and assessment of key performance skills within the context of a comprehensive design project.

For the past six years, a team of institutions in the Pacific Northwest has collaborated to develop engineering design competencies for each year of undergraduate engineering education^{6,7,8,9,10,11,12}. To date the work has included design competencies for the first 2 years of undergraduate engineering education and an assessment system to evaluate student attainment of competencies as entering juniors. Several institutions across the country have piloted or adapted the assessment system for programmatic feedback. Some programs are using the assessment system as a means to support ABET accreditation expectations.

As engineering programs in the United States work to integrate ABET expectations, particularly those focused on engineering design, more information is needed to properly support faculty in this endeavor. To increase understanding of assessment in the context of design capstone courses, a two-phase descriptive study of assessment practices in capstone design courses was conducted. The first phase consisted of a national survey of all accredited engineering programs. The investigation focused on how engineering programs use the senior capstone design project to assess competencies related to ABET outcomes.

The second phase consisted of follow-up interviews with a sample of faculty across multiple institutions. This approach was used to gain in-depth information that could not be obtained from the original survey. Faculty members for this phase were participants in phase 1 who stated they were willing to participate in the second phase of the study.

This paper summarizes findings from this descriptive study and attempts to convey a national portrait of the role and nature of assessment of ABET Criteria 3 and 4 in capstone design courses. The paper presents each phase of the study separately. Discussion and concluding remarks integrate the findings from the two study phases.

Phase 1

Methodology

During spring, 2001, a team of assessment and evaluation professionals and engineering faculty at Washington State University and the University of Idaho, developed initial survey questions to determine use of assessment in capstone design projects. The survey was subsequently piloted at a meeting at Western Michigan University. Administrators and professors from a variety of engineering disciplines participated in the pilot and provided feedback.

After revision, the final survey instrument consisted of 13 items, asking a range of questions about engineering programs in general. Items also asked for information concerning the characteristics of the capstone project including its duration, importance in the undergraduate curriculum, and practices using the capstone design projects to fulfill EC 2000 Criterion 3 and Criterion 4 requirements.

In September 2001, surveys were mailed to the deans of all 274 institutions with accredited engineering programs listed in the ASEE Profiles of Engineering and Engineering Technology reference¹³. Each dean received a packet containing multiple copies of the following items: cover letter, survey, informed consent form, and stamped return envelope. Deans were asked to forward the survey packets to the course coordinators of the capstone design projects in each of their undergraduate engineering disciplines. These disciplines typically include mechanical engineering, electrical engineering, civil engineering, computer engineering, chemical engineering, and environmental engineering. Smaller disciplines were also included. An email follow up was sent to prompt completion of the survey.

A total of 298 responses were received from 119 institutions with accredited engineering programs, a 43% institutional response rate. On average, 2.5 program responses per institution were received, with 4 or more responses from each of 27 institutions. All major engineering disciplines were represented with responses from 15% to 30% of the programs within a discipline. This institutional response rate is comparable to other surveys identified in the engineering literature⁴.

Findings

The majority (57%, n = 171) of faculty indicated that their capstone projects are yearlong, occurring over multiple semesters or quarters. Approximately 50% of the projects occur over a two-semester period, and 8 % take place over three quarters. Thirty-one percent of the projects are scheduled for one semester. Four percent of respondents indicated having a course length of one quarter, 5% a length of two quarters, and 8% reported having capstone course duration spanning three quarters. Figure 1 presents the cumulative percentages of projects conducted from shortest (one quarter) to longest (three quarters or two semesters) durations, showing that slightly over one-third are constrained to a half academic year or less.

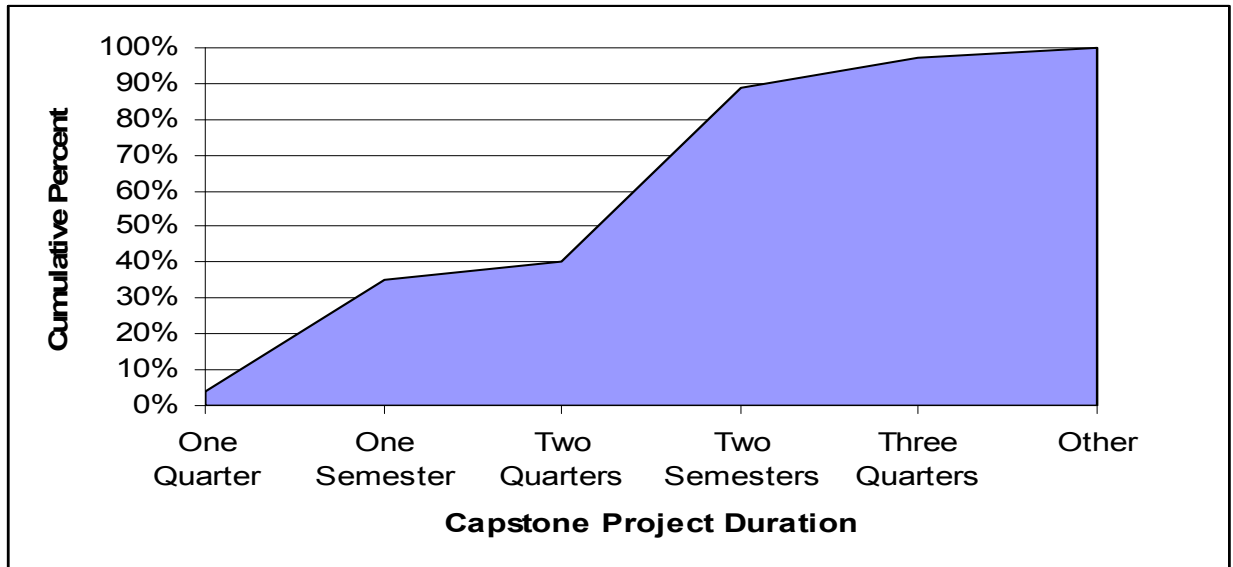


Figure 1. Duration of Capstone Course and Project

Ninety-two percent of the respondents attributed a great deal of importance to the capstone design course, with 59% (n = 175) reporting that it was extremely important and 33% (n = 98) reporting that it was very important. Less than 1% of respondents indicated that the capstone project was unimportant.

The findings are consistent with findings of Todd et al. showing capstone-type courses are strongly encouraged by industry, and considered beneficial by faculty in preparing students for their chosen profession⁴.

When asked how students were organized for the senior design project, 88% of the respondents indicated that students were organized into teams, and 47% reported at least some project teams were comprised of multiple disciplines. Ten percent (10%) of the programs have students work on individual projects. Two percent (2%) of the departments reported the organization of the capstone projects was in a state of transition.

Student participation in project teams vary by discipline. The programs most frequently using team projects with some team members from different degree programs were CptE, EE, and EnvE. Disciplines most frequently having projects with all team members in a single degree program included AgE, ChemE, CivE, and IE. Programs that predominantly use individual capstone projects were BiomE and MSE, although the sample size for these categories is small. Six (6) of the 13 disciplines also have team projects with many students from different degree programs.

When asked what year respondents did or would experience their first accreditation visit under Engineering Criteria 2000, 51% (n = 152) of the respondents reported their first EC 2000 accreditation visit occurred prior to 2002, while roughly 49% (n = 146) indicated that it would occur some time during or after 2002.

Survey participants were also asked to identify which of Criterion 3 expectations and Criterion 4 considerations they believed were appropriate for assessment using the capstone design project, and

which of these competencies they actually evaluate. Several respondents commented they were in the process of redefining capstone program outcomes and developing new instruments and rubrics to assess these outcomes.

Figure 2 shows, in order of endorsement, the Criterion 3 outcomes (and the percentage of respondents) for which they saw assessment potential and those for which they perform assessment in the capstone course. For simplicity, the competencies are abbreviated. On average, eighty percent, (80%, n = 238) of the 298 respondents reported that each of Criterion 3 outcomes can be assessed within the capstone experience, but they also indicated that none of the competencies are assessed to the degree they could be. On average, seventy percent (70%, n = 209) of the respondents indicated that they actually assess each of the a-k outcomes in the context of capstone projects. Communicating effectively (outcome 3g) was reported as the most appropriate outcome for assessment in the capstone course with 97%, (n = 289) of respondents indicating that perspective. The competency deemed the least appropriate (56%, n = 167) for assessing in capstone projects was seeing the need for lifelong learning (outcome 3i). Other outcomes receiving high preferences for assessment were (3e) identify, formulate, and solve engineering problems, (3k) use the techniques, skills, and modern engineering tools necessary for engineering practice, and (3c) design a system, component, or process to meet desired needs. Regardless of the order of preference, faculty indicated that all of the outcomes should be assessed more extensively than is current practice.

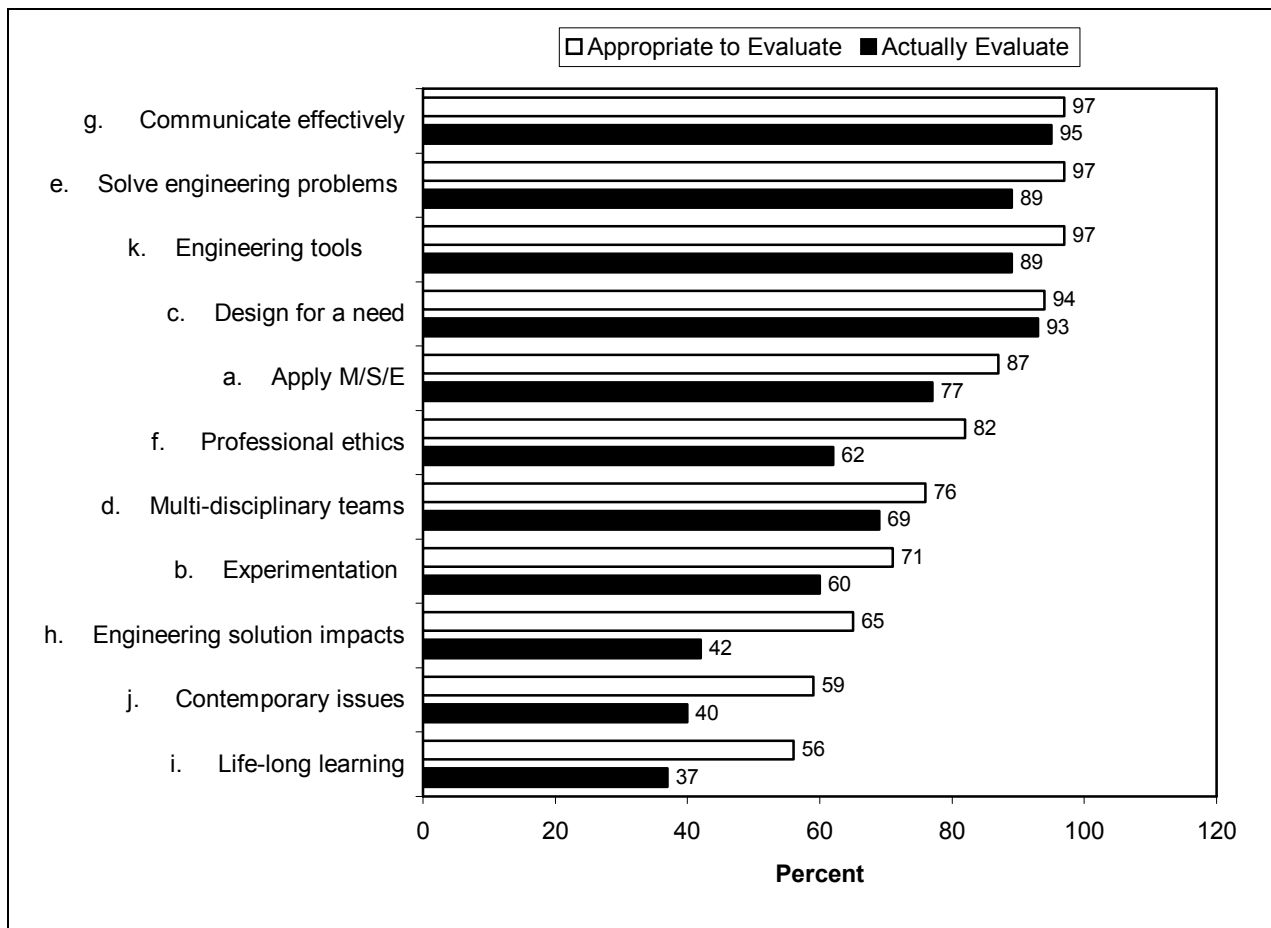


Figure 2. Role of Capstone Design Projects in Criterion 3 Outcomes Assessment

Most disciplines show that all of the Criterion 3 outcomes have high potential for assessment within the capstone experience. At least 50% of the programs within each discipline acknowledge they might assess all of the a-k outcomes, except in three instances. For example, less than 50% of the groups within ChemE, CivE, and MultiDisciplinary consider outcome 3b (to design, conduct experiments, analyze and interpret data) appropriate for assessment in capstone projects. Similarly, less than 50% of respondents within IE, MSE, and MultiDisciplinary indicated that outcome 3i (the need for and an ability to engage in life-long learning) is suitable for assessment in capstone projects. In addition, fewer than 50% of the respondents within BiomE, and MSE believed outcome 3j (understanding contemporary issues) was proper for assessment in the senior design experience. None of the BiomE respondents considered outcome 3h (understanding the impact of engineering solutions in a global/societal context) an apt assessment target for the capstone design experience. In the same way, outcome 3b (design, conduct experiments, analyze and interpret data), and outcome 3i (recognize the need for and an ability to engage in life-long learning) were identified as inappropriate for assessment there by all respondents in the nuclear engineering discipline.

Figure 3 shows, in order of priority, the Criterion 4 prescribed design constraint considerations and the number and percentage of respondents with respect to assessment suitability and practice. Compared to Criterion 3 outcomes, fewer respondents reported Criterion 4 design constraint considerations appropriate for assessment in the capstone project. When considering the outcomes individually, on average, 50% of the respondents indicated a specific constraint appropriate for assessment in their capstone projects. Ninety-two percent believed economic considerations were appropriate for assessment. Political considerations were reported as the least suitable for assessment in the capstone project. More than 70% of the respondents, in order of preference, noted economic, environmental, health and safety, and ethical considerations as being appropriate for assessment in capstone projects. However, respondents reported that none of those items are currently being assessed to the level possible. Fewer than half of the participants reported sustainability, social considerations, manufacturability, or political considerations were suitable for evaluation in capstone projects. Respondents reported all but one of the Criterion 4 considerations were not being assessed as much as they believed possible. However, more programs (59%) assess manufacturability considerations in the capstone project than deemed this assessment appropriate (42%).

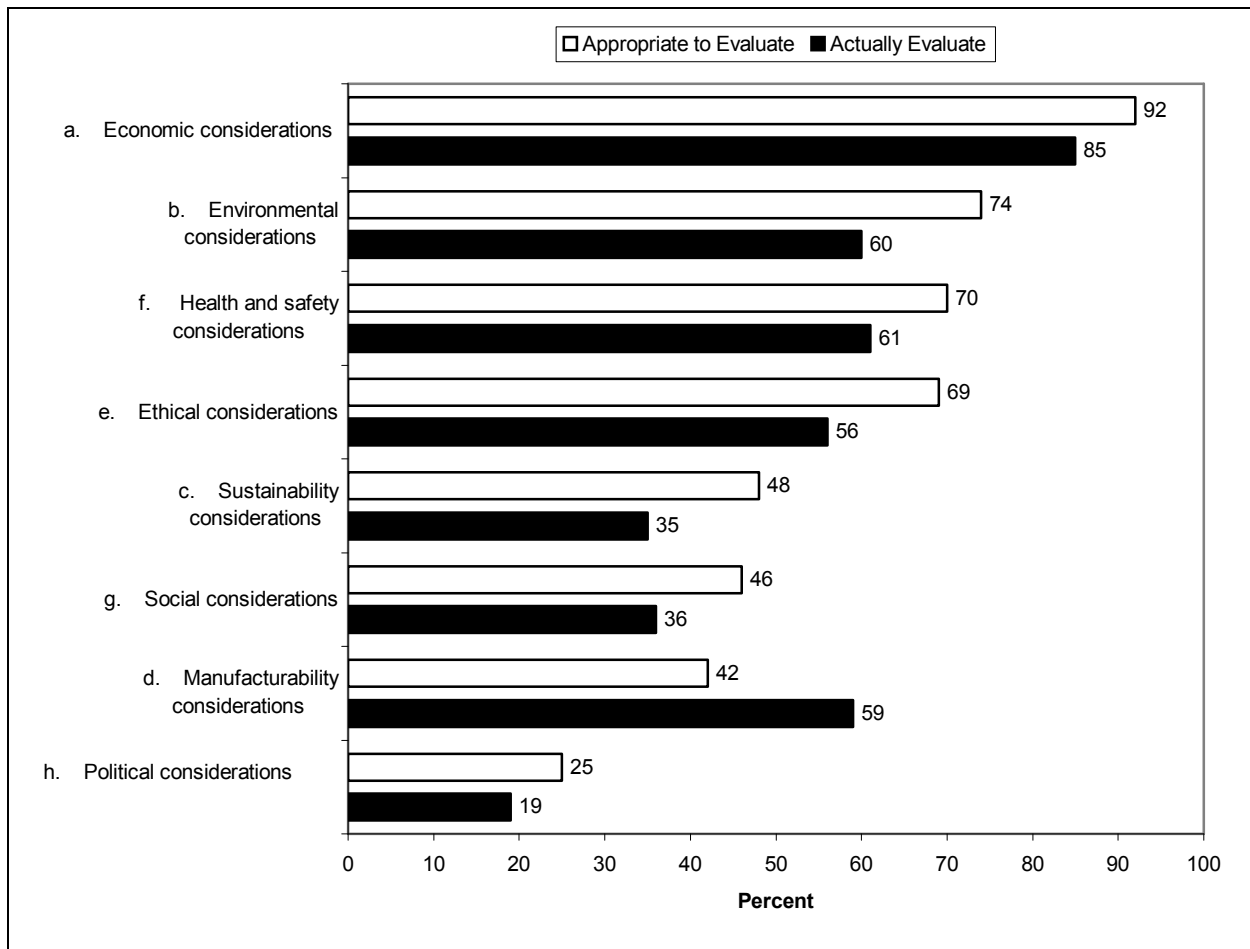


Figure 3. Role of Capstone Design Projects in Criterion 4 Outcomes Assessment

Summary of Major Findings

- The majority of faculty indicate that their capstone projects are yearlong, occurring over multiple terms
- 92% of the respondents attribute a great deal of importance to the capstone design course
- When asked how students were organized for the senior design project, 88% of the respondents indicated that students were organized into teams
- Student participation in project teams vary by discipline
- 80% of the respondents report that each of ABET Criterion 3 outcomes can be assessed within the capstone experience, but they also indicated that none of the competencies are assessed to the degree they could be
- 70% of the respondents indicate that they assess each of the a-k outcomes in the context of capstone projects
- Compared to Criterion 3 outcomes, fewer respondents report Criterion 4 design constraint considerations appropriate for assessment in the capstone project

Implications

These findings suggest the following implications:

Duration of Capstone Experience. ABET Criterion 4 emphasizes product realization including detailed capstone design, prototype testing and design verification. Earlier ABET criteria encompassed primarily conceptual design. Consequently, a possible shift has occurred in the duration of the capstone experience to allow more comprehensive project experiences. In 1995, Todd et al. reported a large percentage of departments (45%) did both class instruction and a project in one semester. Today the number with one-semester projects has diminished to 31%. Those authors also stated that only 36% of responding departments had a course length of two semesters. From our survey, forty-nine percent (49%) of projects are currently two semesters in duration.

Importance of Capstone Course. EC 2000 Criterion 4 requires an integrative project experience that encompasses a range of realistic considerations. Our survey results showing longer project durations may suggest that faculty are responding to the need for more comprehensive projects while also addressing more of the Criterion 3 outcomes.

Composition of Teams and Projects. The organization of students working on design projects may also be changing. Our data suggests that the capstone design project offers significant potential for assessing students' abilities to work in teams, and in nearly half the cases, to work in multidisciplinary teams (as per Criterion 3d) with each team working on a different project. These percentages are higher than those reported by Todd in 1995, with 62% of their respondents showing all students in a given class worked on the same project, and 38% reporting 1-7 students were assigned to a team working on the same projects. The current survey found that only 10% of programs have projects done by individual students.

Emerging Opportunities for Multidisciplinary Teams. The number of programs that emphasize a team experience for the capstone projects, and those with multi-disciplinary teams, suggest that EC 2000 accreditation criteria (e.g., outcome 3d- function on multidisciplinary teams) may be a factor in determining the student composition of teams. Although multi-disciplinary teams create additional management challenges, increasing numbers of programs are finding ways to provide students these learning experiences.

Appropriateness of Capstone as Focus for Outcomes Assessment. The majority of faculty believe all Criterion 3 (a-k) outcomes are appropriate to evaluate in the capstone design course; approximately one half of these outcomes (b, h, j, and i) are assessed significantly less than believed possible. The disparity between actual and potential assessment of outcomes may reflect early stages of modification. These findings suggest a lack of preparedness among faculty to effectively develop and manage assessments of some of these outcomes. Many respondents commented on the survey that they were in the process of revising, or planning an extensive revision of, their senior design program outcomes and associated assessment instruments.

Confusion Surrounding Criterion 4. Fifty percent (50%) of the design constraint considerations (c, g, d, and h) were reported as being appropriate for assessment in capstone design. Whereas many of Criterion 3 outcomes are developed in the first three years of the curriculum, Criterion 4 design constraint considerations do not usually occur prior to the senior capstone experience.

Consequently, capstone course faculty encountering these new Criterion 4 constraints for the first time may find these difficult to integrate adequately into the capstone experience, creating challenges also for faculty seeking to determine if they have been addressed adequately. Note also that criterion 3 expectations are referred to as outcomes, and are stated with some detail. This detail provides a solid basis to fashion assessment of outcomes. On the other hand, Criterion 4 lists design constraint considerations to be included in capstone project experiences. These considerations are stated in an open-ended fashion that allows flexibility in their application but also poses unique assessment challenges for faculty.

Phase 2

Methodology

Two engineering faculty and one assessment specialist developed open-ended questions for the follow-up interview phase of the study. After completing the first draft of the instrument, two capstone faculty at University of Idaho, and four capstone faculty at Seattle University were interviewed to pilot the questionnaire. All six of these capstone instructors had completed the national survey, and were self-identified as collaborators for the phase 2 assessment project. Each interview lasted approximately 45 minutes.

During fall 2001 and spring 2002, on-site interviews were conducted. Each interview was audiotaped and lasted approximately 45 minutes. Artifacts such as course syllabi, assessment instruments, and scoring rubrics were collected from participants.

Interviews were conducted with 47 faculty members from 10 institutions in the Northwest, and three from the Southeast. In addition, the interview protocol was converted to questionnaire format and administered to an additional 47 faculty members on-line. In this way, more in-depth information could be obtained, broadening the sample of faculty members and programs represented, but doing so in a cost effective manner. The findings from the interviews and on-line version were combined for this phase of the study.

Analytical Framework

The qualitative data obtained from the interviews and on-line questionnaire are categorized and analyzed using Stiggins' five Standards to Quality Assessment¹⁴. Although several assessment standards exist, Stiggins' standards are widely accepted among educators in the United States². Moreover, the simplicity of the standards and common sense definitions provide a useful means to consider the quality of assessment practices within engineering programs. These standards include: (1) the user understands and has articulated the purposes for the assessment, (2) clear and appropriate achievement targets are assessed, (3) a good match between the achievement target and available assessment methodology is made, (4) a sufficient sample of student achievement information is obtained for a particular assessment purpose, and (5) steps were taken to eliminate bias and distortion of achievement data. Findings and implications are presented for each assessment standard.

Findings

Users and Uses. Faculty members were asked to identify the uses and users of the assessment information. Respondents indicated the assessments serve a number of purposes within a given department. The most frequent responses reported that assessments provide feedback to capstone faculty (76%, n = 75), and to capstone students for monitoring student progress (65%, n = 64). Assessments also inform non-capstone course faculty, department administration, and industry clients (43%, n = 42). Some have faculty from neighboring departments or institutions that use assessment results to benchmark their respective programs. These results are depicted in Figure 4.

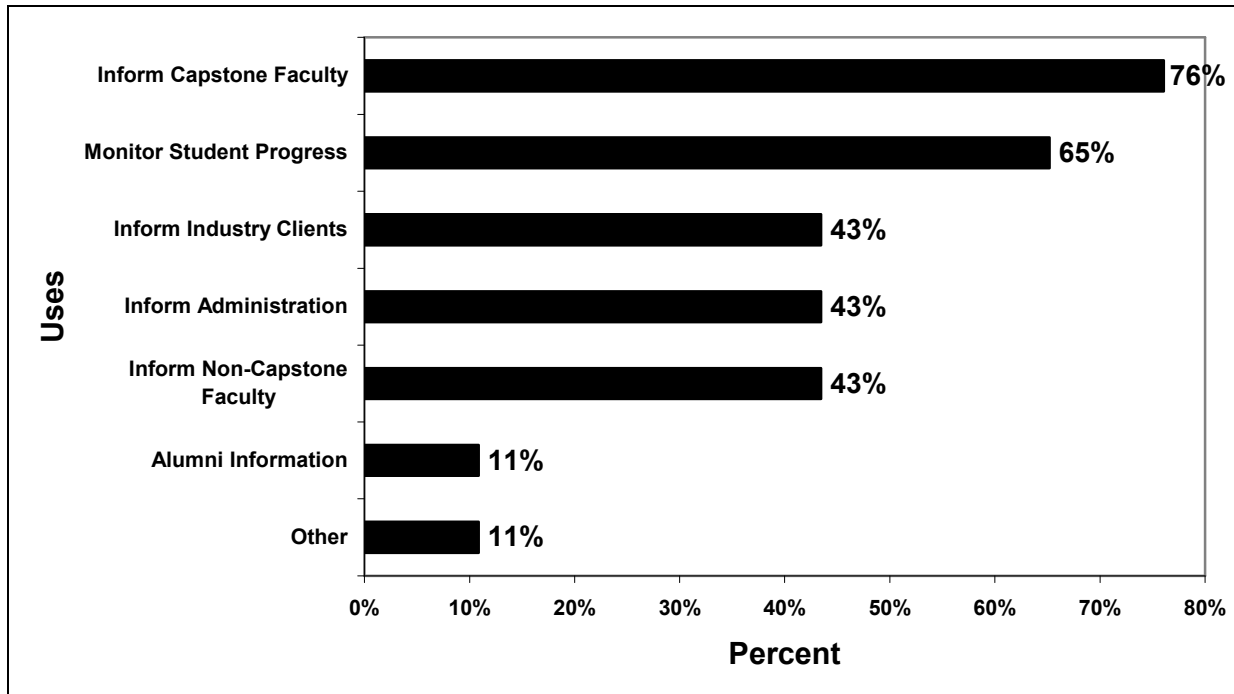


Figure 4. Uses of Capstone Course Assessments.

Multiple stakeholders use the results of capstone assessments and participate in their administration. Ninety percent (n = 85) of the capstone faculty respondents participate in the assessment of capstone outcomes. Some programs rely on advisors, coaches, other faculty, or members of administration to play more active roles in assessments. This is often due to very large numbers of students and projects in a given discipline. Industry sponsors or clients participate in 68% (n = 64) of assessment activities. Seventy percent (n = 66) of the respondents said students participate in assessments, and this predominantly occurs with oral presentations. A few (9%, n = 8) have project centers or similar organizations that appraise student progress.

Appropriate Targets. Several questions were posed to faculty concerning educational objectives that act as targets for the capstone experience. Instructors were asked about the type of capstone objectives they used, where written copies of the objectives were located, how they were communicated to students, and how well they felt students comprehended the objectives for the course.

Eighty-seven (87) percent (n = 82) of the respondents reported that the objectives of the capstone project were very similar to selected ABET Criterion 3 (a-k) learning outcomes. A matrix typically cross-referenced the ABET criteria to the individual capstone course number and its prerequisites. In reviewing each course syllabus, however, it appeared the major emphasis for the capstone course focused on project milestones rather than educational objectives. These project milestones were specific and typically managed by the use of Gantt charts. Ten percent (n = 9) of faculty reported their academic targets were independent of ABET outcomes, while two percent (n = 2) indicated they were identical to those listed in the ABET criteria. Only four of the programs reviewed had both project milestones and educational objectives listed as targets. Respondents intimated that very little new information was taught in the capstone experience, and consequently it was difficult to equate educational objectives with the capstone project.

All faculty members reported that discerning the meaning of outcomes associated with Criterion 4 was more difficult than those of Criterion 3. Further, a common practice used by faculty delineated the goals of the course from a global perspective such as: implement the design process, demonstrate teamwork and communication, complete the project, and develop professionalism suitable for engineering practice. Several programs did have departmental objectives in addition to the outcomes associated with Criterion 3.

Faculty members defined project milestones and expectations in multiple documents or locations. Ninety-four percent (n = 88) of the respondents reported capstone outcomes were listed in the course syllabus. Twenty-eight percent (n = 26) also provided them on the department web page. Twenty percent (n = 18) also outlined the course requirements in the college catalog, or stipulated expectations with individual assignments throughout the capstone experience. Handouts were the preferred method for 9% (n = 8) of the instructors.

When asked how capstone outcomes were communicated to students, faculty said multiple methods were employed. Ninety-one percent (n = 86) of the respondents reported the expectations and milestones of the course were explained as part of the course introduction on the first day of class. This was usually achieved while discussing the course syllabus. Over 50% of the faculty revisited those expectations via course discussions, as part of course assessments, or as question and answer sessions after the students re-read the course syllabus. Other communication methods included memoranda as the course progressed, and focus group sessions where previous students discussed the previous year's projects. A few capstone instructors explained that students were expected to maintain a journal, reflecting self-progress in relationship to project milestones.

Faculty were queried on their student's understanding about what they were expected to know and be able to do at the end of the senior capstone design experience. Fifty-three percent (n = 50) reported their students understand and value the objectives of the course. Twenty-one percent (n = 20) believed their students could at least articulate the objectives of the course. However, only 7% of the faculty felt seniors understood and valued the objectives of the course to the extent that they routinely used them to monitor their own progress or performance. Only two faculty members said their students did not understand the objectives of the capstone experience.

Target/Method Match. In order to investigate the appropriateness of applying proper assessment methods for the capstone course, several questions were posed with the knowledge that the use and

users, as well as targets for the project/course had been identified by previous faculty responses. These queries included the types of assessments being used, who participated in the assessments, and the nature of the assessments.

The number and types of assessments varied, but all faculty members interviewed indicated they engaged in multiple assessments throughout the capstone course. This information is presented in Figure 5. Ninety-four percent (n = 88) of the capstone instructors reported students were assessed during oral presentations. These assessments typically occurred multiple times during the course. More than two thirds (68%, n = 64) of the faculty indicated that the verbal reports were also assessed by students' peers. The oral presentations often accompanied written reports concerning the status of the project. Seventy-seven percent (n = 72) of the respondents used intermediate written reports as assessment data points, while 91 percent (n = 86) also required a final written report. Faculty used a myriad of other measures including student surveys during and at the end of the course, self-reflection entries in journals, self-reflection papers, alumni surveys, notebooks, log books, student written user's manuals, exit surveys, and assessments by a consortium of faculty within a capstone project center. Less than 15 % of the faculty assessed students via portfolios, focus groups or interviews. Assessment for accountability was characteristic of most institutions. Several faculty required students to keep a time log to monitor hours devoted to the project. Others reported that students were not allowed to graduate if their computer programs or other design products did not work. This high stakes accountability was often evident in mechanical, computer science, and computer engineering disciplines.

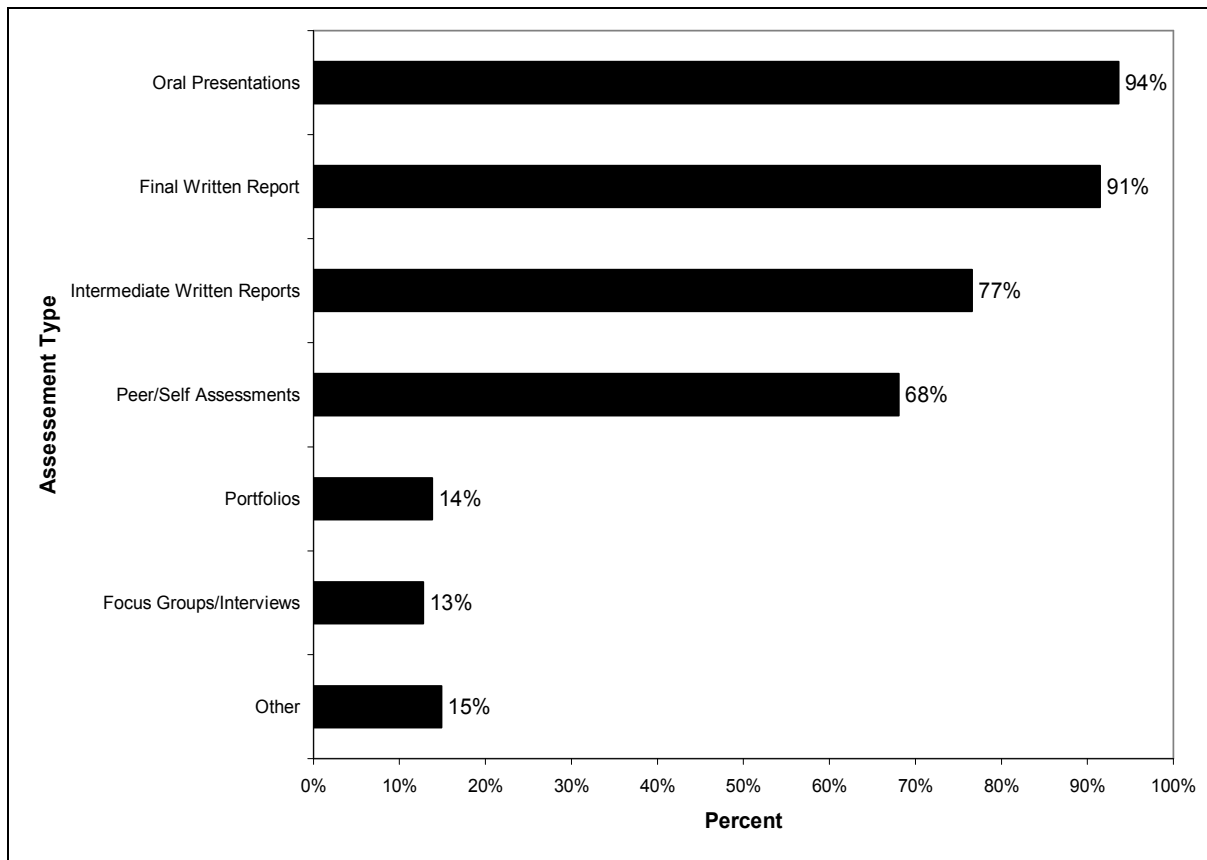


Figure 5. Assessment Methods Administered during Capstone Experience.

The nature of the assessments used by capstone instructors varied. When capstone instructors were asked to describe the characteristics of their assessments, 40% (n = 38) of the respondents said their measures were detailed in nature based on careful analysis of student performance against course objectives. Thirty percent (n = 28) related that the course assessments were also detailed in nature, but not specifically tied to course objectives. Holistic scoring was reported as characteristic of 19% (n = 18) of the assessments. Two faculty mentioned their assessments were a combination of all three categories, depending on what outcome or competency was being measured. For example, oral presentations may have been individually scored based on definitive criteria, whereas written reports may have been team scored with more subjective standards. Careful examination of artifacts revealed that scoring rubrics were typically subjective in nature. For example, a grading scale of 1-X was often used for a specific assessment, but lacked clear performance criteria associated with the various levels of proficiency.

Sufficient Sample of Student Achievement Information. Two questions were asked in order to investigate what methods were used to ensure that sufficient content areas were assessed so faculty were confident that students had mastered the intended outcomes. First, faculty were asked to describe their grading practices. Second, instructors were asked to depict the levels of proficiency last year's graduating seniors had attained.

For 71% (n = 67) of the respondents, senior capstone design course grades were individually assigned based on integrated individual performance. In contrast, nine percent (n = 8) of the faculty said the final grades received by their capstone students were the same for all team members based on integrated team performance. Nineteen percent of the faculty (n = 18) explained that their grading practice was a combination of these approaches. For example, a team would submit a final written report on the project and all team members received the same grade for the report. On the other hand, oral presentations were individual efforts for the most part, and these students received individual scores. The final grade was an amalgamation of these and other factors. Only one faculty member reported the course grade was the same for all team members based on weakest team performance in the competencies addressed by the course.

Capstone professors were given descriptions of three levels of proficiency: (1) engineering intern – an individual who has only cursory knowledge and skills necessary for engineering practice, (2) entry level engineer – an individual who has a mastery of basic knowledge and skills necessary for engineering practice, and (3) project engineer – an individual who has advanced engineering knowledge and skill and has demonstrated the potential to lead design projects and/or manage or mentor practicing engineers. Faculty were then asked to categorize, by percentages, how many students in the last graduating class fell into each of these groups. Respondents related that 10% to 30% of the class had attained intern level proficiency, 70% to 90% entry level status, and 10% to 30% project engineer status. Students who had prior industry experience, were employed by industry as summer interns, or were currently employed by an engineering firm were more likely to demonstrate a skill set comparable to project managers and leaders.

Some professors interviewed indicated that graduating intern level engineers may be due to the quality of assessments for determining individual design performance, as shown by these statements.

Professor A: *“It’s very easy to ensure teams have mastered the milestones or outcomes; the problem is the individual. What we’ve decided to do this year is require a design portfolio that will require work from other courses as well as the design project.”*

Professor B: *“I’m not getting a good sense of individual accomplishments and contributions because everything they submit is on behalf of the team. The only thing I have is my own impressions from talking to them about their journals, and the peer evaluations at the end.”*

A final issue associated with assessing students’ competencies upon graduation is the lack of clear communication. No capstone faculty indicated that anyone sat down with students on an individual basis offering an explanation of their strengths and areas for improvement. Fifty percent (50%, n = 24) said that “the poor students know who they are,” and that “grade inflation due to team scoring” was a prevalent challenge to overcome.

Control for Bias and Distortion. Faculty members were asked to describe how their students might classify the fairness of the assessments used in the capstone course. In addition, questions were posed regarding faculty’s perceptions on how their assessments might be improved, and what training they had received or desired to have regarding writing educational objectives or developing assessments. (NOTE: Queries on professional development history in regard to writing educational objectives and developing assessment tools were posed to all on-line respondents (n = 47), but to only five faculty participating in on-site interviews due to interview time constraints.)

Five categories were used to catalog faculty perceptions with the following descriptors of fairness: (1) unclear - I hear lots of complaints, (2) tricky - I hear some complaints, (3) fair - I seldom hear complaints, (4) very fair - I get positive feedback about the assessments, and (5) all bias and distortion have been eliminated - I receive accolades from students and faculty alike. Approximately one-half of the respondents (51%, n = 48) said they seldom heard complaints, and students felt the assessments were fair. Less than one-third of the instructors (30%, n = 28) stated that students’ reactions suggested that the assessments were very fair. These faculty reported positive feedback about the assessments, and typically the capstone experience was the most practical and enjoyable course of the curriculum. None of the respondents indicated that all bias or distortion had been eliminated, where they had received praise from both students and faculty for the excellent quality of the assessments.

Faculty identified several ways they wanted to improve the quality of their capstone assessments. About one-half of the respondents felt the measures should be more objective with 49% (n = 46) wanting to develop more detailed scoring guidelines/rubrics, and 47% (n = 44) desiring clearer performance criteria. Forty-three percent (n = 40) of instructors also wanted to increase the variety of assessment instruments. Only 26% (n = 24) wished to define the objectives of the capstone course more clearly. Three faculty felt assessments were of little value because industry would continue to hire their graduates regardless of the efforts spent on improving the quality of the measurements.

All faculty who completed the on-line questionnaire answered a question concerning how much training they had received in writing educational objectives or developing assessment instruments. More than half of the respondents (57%, n = 29) had attended one or more workshops on writing

educational objectives, but less than eight percent, (n = 4) had completed one or more college courses on that topic. Almost two-thirds of the respondents (61%, n = 31) indicated they had attended one or more workshops on developing assessment instruments. Only ten percent (n = 5) received college credit on assessment subject matter. One-fifth of the faculty (20%, n = 10) had no training on either topic. Workshops that faculty attended were often facilitated or sponsored by representatives of ABET.

Summary of Major Findings

- Respondents indicate that assessments serve a number of purposes within a given department including feedback to capstone faculty (76%), feedback to capstone students for monitoring student progress (65%), and information to non-capstone faculty, such as administrators (43%)
- 90% of capstone faculty respondents participate in the assessment of capstone outcomes
- 68% of respondents indicate that industry sponsors or clients participate in assessment activities
- 87% of respondents report that the objectives of the capstone project are similar to selected ABET Criterion 3 outcomes
- All faculty members report that discerning the meaning of outcomes associated with Criterion 4 is more difficult than those of Criterion 3
- Faculty members define project milestones and expectations in multiple documents or locations (e.g., course syllabi, department web page)
- Faculty report multiple methods for communicating capstone outcomes to students (e.g., course syllabi, ongoing communication with students)
- Faculty report a variety of methods for assessing capstone outcomes with 94% using oral presentations, 68% using peer assessments of verbal reports, and 77% using written reports
- 71% of respondents indicate that senior capstone design course grades were individually assigned based on integrated individual performance
- When given descriptions of proficiency, respondents indicate that 70% to 90% of students achieved entry-level status
- Most faculty report a desire to improve their assessment practices
- While many faculty report receiving some assessment training through workshops, 20% report no assessment training

Implications

Findings from phase 2 of the study suggest that faculty members understand that different stakeholders or users have different information needs and that, therefore, different assessments for the same program could be needed.

Although 90% of the respondents indicated their expectations and objectives were similar to ABET outcomes, clarifying achievement expectations is a potential area for improvement for capstone instructors. One veteran of three decades of facilitating capstone courses supported that suggestion with the following statement, *“Most faculty agree that having more clearly defined objectives for the capstone course is something they need to work on. The difficulty is they have been saying that for 30 years. It really is anathema to most faculty to put down their thought processes on paper and*

make it an orderly process, and connect that with students. They do in fact, know what they're doing for the most part, and for the most part, it works. But getting it articulated and getting it written down, it's not their nature."

Capstone instructors spend a considerable amount of time and effort in communicating expectations for the capstone course and project. The fact that only 7% of the respondents believed their students referenced the objectives of the course to monitor their own performance indicates a possible lack of specificity in the intended outcomes. That lack of specificity has the potential to lead to inconsistency in how the course is administered.

Faculty could potentially benefit from extended training on writing educational objectives, or from the presence of a permanent, full-time, classroom assessment specialist who could conduct in-service training for assessment, and offer technical support on demand.

Collection of artifacts indicates the performance expectations being assessed are more closely related to project milestones than educational objectives, and are typically holistic or somewhat subjective in nature. Assessments generally are product focused rather than process focused.

The capstone experience provides a unique challenge in assessing a wide range of competencies that theoretically have been achieved earlier in the curriculum. As one senior faculty capstone instructor noted, *"One thing you have to keep in mind is we are trying to look at a more integrated performance during the senior project, so it cuts across multiple objectives or outcomes. If you try to have measurement instruments that are too specific, you may miss those that cut across several competencies. So there is more qualitative judgment for the senior project than there would be in other courses."*

Faculty appreciate the importance of measuring student achievement given the types of assessments employed, and the wide assortment of assessment participants and users.

New faculty might profit from an in-depth orientation session on assessment literacy and assessment practices employed at their institution. This training might also include strategies for involving students in the assessment process as a means to help them see and understand the achievement they are expected to attain. One key to their success as capstone faculty is their competency in communicating effectively about student achievement.

Summary and Conclusions

This paper described the results of a nationwide survey concerning the assessment of ABET Engineering Criteria 3 and 4 expectations within the context of a comprehensive design project. In-depth information about assessment practices was also obtained from a sample of faculty members.

A majority of respondents felt that all competencies cited by Criterion 3 and half of the design constraint considerations cited by Criterion 4 of EC 2000 were appropriate for evaluation in the capstone design course. Respondents also indicated that those competencies suitable for assessment should be evaluated more extensively than is current practice. Criterion 3 outcomes appear to have sufficient specificity that enables faculty comprehension of ABET's expectations, so their

assessment is fairly straightforward. In contrast, the lack of specificity in Criterion 4 design constraint considerations makes assessment of them considerably difficult.

The implementation of the outcomes-based engineering accreditation criteria has heightened faculty awareness of the importance of the capstone experience. The study documented a nationwide interest among capstone design faculty to collaborate on the development of capstone assessment instruments.

Findings from the second phase of the study show that faculty understand that a variety of assessment users require information in different formats. A variety of objectives have been developed and communicated to students. Faculty use different assessments in their courses, use differing amounts of achievement information for course grades, and suggest a variety of techniques could be used to control for bias and distortion of the achievement information.

However, faculty members suggested that they lacked information and know-how to develop assessments for all users, write clear and appropriate course objectives, and determine whether assessments used in courses are as fair as desired. Many faculty members stated that assessment know-how is more important than ever, and that assessment training could be used productively to meet this need.

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