

2006-1180: A REVIEW OF LITERATURE ON ASSESSMENT PRACTICES IN CAPSTONE ENGINEERING DESIGN COURSES: IMPLICATIONS FOR FORMATIVE ASSESSMENT

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A Review of Literature on Assessment Practices in Capstone Engineering Design Courses: Implications for Formative Assessment

Abstract

This paper presents findings from a literature review on classroom assessment in capstone engineering design courses. Nine engineering education and design journals and conference proceedings were queried, going back 10 years. Based on specific criteria, thirty-two articles were identified for review. Findings show a focus on description of classroom assessment techniques and their general use. Three articles specifically focus on the use of formative classroom assessment to enhance student design competence and professional skills. The literature, while emerging, is fragmented and diffuse. Implications for classroom assessment practice and scholarship in engineering education are addressed.

Background

A critical component of the education and training of engineering professionals is the capstone design course. The purpose of this course is to provide a culminating experience for senior engineering students that foreshadows the type of project work practicing engineers encounter on the job. In these courses students must work under real-world constraints on ill-defined problems, typically in teams, and often receive industry feedback during various phases of a design project¹.

A recent national survey of capstone engineering design course instructors across programs and disciplines found that respondents reported using the capstone design course to document student achievement for accountability and accreditation purposes². However, respondents also reported uncertainty with using classroom assessments to enhance student achievement or ways to use assessment to achieve capstone design course outcomes.

Of particular interest for this paper is the extent to which classroom assessment (in contrast to program assessment) has received attention in the literature by faculty and other researchers in capstone design coursework. While the literature is replete with examples of assessment used for reporting of student achievement or program evaluation, the extent to which the literature deals with classroom assessment is not readily apparent. In addition, we sought to discover what has been learned about the conduct of capstone design classroom assessment that could be used to enhance student achievement, that is, classroom assessment used for formative purposes.

Classroom assessments are at the heart of the teaching and learning process, and likely the assessments most important to students³. Classroom assessments can reveal to students course expectations, whether or not a student is on the right track in pursuit of

the outcome, and possibly, what the student might do to meet expectations. We argue that classroom assessment in the context of engineering design capstone courses has enormous potential for student achievement and that it is therefore, important to understand current thinking and practice related to classroom assessment in capstone design courses.

Methodology

Search for articles and papers started with the identification of key conference proceedings and journals likely to contain work on classroom assessment in capstone engineering design courses. For each proceeding or journal, we searched articles published within the last 10 years. In addition, references for each identified article were examined. Using this branching technique, several more articles were identified for possible inclusion in the review. This initial process identified 151 articles. Authors discussed each article and worked to consensus on whether to review the article. Article abstracts were read and, if necessary, the article was skimmed to determine whether it could be placed in one of the following categories:

High Priority: articles that deal specifically with classroom assessment in capstone engineering design courses

Priority: articles that deal with projects in capstone engineering design courses that have implications for classroom assessment or articles that deal with classroom assessment in the context of other engineering design courses

Low Priority: articles that focus on classroom assessment of non-capstone courses

We also sought agreement on the type of scholarship employed in each retained article as well as the evidentiary basis for any claims made by the article's authors.

Findings and Discussion

After considering titles, reading abstracts, skimming articles, and discussion among the authors, 32 papers were retained for the review. Fifteen of the articles were classified as high priority, eight priority, and nine low priority. Fifteen articles were obtained from engineering education conference proceedings, 12 from engineering education-oriented journals, four from design-oriented journals, and one from a communications journal. The complete set of articles retained for this review is identified in the bibliography.

Most articles described techniques in assessment and their use in the classroom. A sample of these purposes includes the use of standardized measures to assess content knowledge in design⁴; peer reviews, self assessments, and oral reports, all used to evaluate student performance as team members and design engineers⁵; and project expectations and scoring criteria for the assessment of completed design projects⁶.

The type of scholarship found in the literature varied. Seven articles were classified as basic research. That is, for these works, a literature review was conducted, research questions formulated, a methodology to answer the questions developed, findings

produced, and implications addressed. Seventeen articles were applied in nature. Nine of these articles focused on the program (with some attention to the classroom or student), while eight focused almost exclusively on the student. Four conceptual articles were found. These articles attempted to broaden understanding of student outcomes or classroom assessment in capstone engineering design courses. Two surveys and two literature reviews were also found in the search. Most articles were self-reports by the authors.

Table 1 provides a summary of all articles reviewed for this paper. The table describes where the article is located, the type of scholarship used by the authors of the article, and its connection to student achievement. Note that the article numbers correspond to the bibliography of reviewed articles.

Table 1

Summary Information of Articles

Article (with bibliographic number)	Archival Location	Type of Scholarship	Connection to Student Achievement
High Priority			
1. Adams & Atman (1999)	Engineering Education Conference Proceedings	Basic Research	Provides a means to identify more effective pedagogical approaches to design education
4. Atman & Bursic (1998)	Engineering Education Journal	Basic Research	Highlights a means to assess student understanding of design
5. Atman et al. (1999)	Design Journal	Basic Research	Comparison of freshman and senior engineering design processes
6. Bass & Begovic (1997)	Engineering Education Journal	Applied Research (student focus)	Illustrates capstone design course in electrical engineering
9. Brackin & Gibson (2001)	Engineering Education Conference Proceedings	Applied Research (student focus)	Emphasizes the use of company evaluations, oral reports, student self- assessments

Article (with bibliographic number)	Archival Location	Type of Scholarship	Connection to Student Achievement
10. Brackin & Gibson (2002)	Engineering Education Conference Proceedings	Applied Research (student focus)	A discussion of the use of a variety of assessment techniques for industry sponsored capstone design projects
16. Davis (2004)	Engineering Education Conference Proceedings	Applied Research (student focus)	Illustrates a variety of accreditation requirements program and classroom assessment opportunities in a capstone design course
20. Magleby et al. (2001)	Engineering Education Journal	Applied Research (program focus)	Addresses importance of selecting industrial projects for capstone design course
21. McKenzie et al. (2004)	Engineering Education Conference Proceedings	Survey Research	Identifies assessment as key to student achievement
22. Quadrato & Welch (2003)	Engineering Education Conference Proceedings	Applied Research (program focus)	Offers approach to capstone design projects that provides clear expectations for students
24. Salama et al. (2004)	Engineering Education Journal	Applied Research (program focus)	Provides senior capstone design projects in electrical engineering a progress Assessment for team Performance and individual achievement

Article (with bibliographic number)	Archival Location	Type of Scholarship	Connection to Student Achievement
25. Shaeiwitz (2001)	Engineering Education Journal	Applied Research (student focus)	Illustrates vertical integration of design curriculum and feedback students receive on Projects
26. Sobek & Jain (2004)	Engineering Education Conference Proceedings	Applied Research (program focus)	Stresses importance of valid measurement of design outcomes
27. Taylor et al. (2001)	Engineering Education Journal	Applied Research (student focus)	Stresses the importance of the faculty member as coach in assisting student design teams
32. Walker & King (2003)	Engineering Education Journal	Basic Research	Studies assess expert- novice differences in conceptual understanding of biomedical engineering design process
Priority			
2. Adams, Turns, & Atman (2003)	Design Journal	Basic Research	Discusses the importance of reflective practice for student learning in design
11. Brinkman & van der Geest (2003)	Communica tion Journal	Applied Research (student focus)	Describes student feedback on technical communication in engineering design courses

Article (with bibliographic number)	Archival Location	Type of Scholarship	Connection to Student Achievement
12. Busseri & Palmer (2000)	Design Journal	Basic Research	Self-reflection and monitoring
15. Davis et al. (2003)	Engineering Education Conference Proceedings	Conceptual	Offers tentative list of capstone design course outcomes
17. Downey & Lucena (2003)	Engineering Education Journal	Applied Research (program focus)	Examines how focus on engineering science can undermine student responsiveness to engineering design
19. Little & King (2001)	Engineering Education Journal	Applied Research (program focus)	Offers selection criteria for industry sponsored capstone design projects
28. Todd et al. (1995)	Engineering Education Journal	Survey Research	Provides snapshot of capstone courses structure, project type, and faculty involvement as a means to understand current programs and gauge student benefit
30. Turns & Atman (2001)	Engineering Education Conference Proceedings	Applied Research (program focus)	Describes the evaluation of a capstone design course in industrial engineering

Article (with bibliographic number)	Archival Location	Type of Scholarship	Connection to Student Achievement
Low Priority			
3. Atman, Admans, & Admans (2000)	Engineering Education Conference Proceedings	Applied Research (program focus)	Illustrates the use of multiple methods for evaluation of instruction and course content in a freshman design course
8. Beyerlein et al. (2004)	Engineering Education Conference Proceedings	Conceptual	Offers process for developing performance measures
7. Baya & Leifer (1994)	Engineering Education Journal	Applied Research (program focus)	Provides framework to assist with evaluation curriculum and the assessment of student learning of design
13. Campbell & Colbeck (1997)	Engineering Education Conference Proceedings	Applied Research (student focus)	Illustrates the impact on student achievement of the reflective essay
14. Cupp, Moore, & Fortenberry (2004)	Engineering Education Journal	Conceptual	Use of concept maps for a variety of assessment purposes
18. Kline et al. (2003)	Engineering Education Conference Proceedings	Conceptual	Offers hierarchy of cognitive domain learning skills

Article (with bibliographic number)	Archival Location	Type of Scholarship	Connection to Student Achievement
23. Safoutin et al. (2000)	Design Journal	Basic Research	Broadens understanding of engineering design
29. Turns (1997)	Engineering Education Conference Proceedings	Literature Review	Reviews research on teaching and assessment of design
31. Turns, Atman, & Adams (2000)	Engineering Education Conference Proceedings	Literature Review	Offers a means to develop pedagogy, assessment and monitor faculty implementation

Most articles have a tangential relationship to student achievement. These articles discuss or argue for specific outcomes in capstone design courses, provide a structure to deal with assessment and evaluation, or broaden understanding of how senior-level students conceptualize design tasks and activities.

Only three articles were identified that expressly illustrate the use of classroom assessment for formative purposes in capstone design or related courses. The articles identify the assessment method, process, and connection to student learning. The work discussed in these articles has strong ramifications for the enhancement of student learning in capstone design courses. Each is discussed in detail.

First, Turns offers the classroom assessment strategy of learning essays in undergraduate engineering design courses⁷. The idea behind this approach is that students reflect on their project experiences and write essays in response to guided questions. This occurs eight to 10 times per term. The questions are strategically developed and offered to provide scaffolding for students as they reflect on their learning and come to understand design. Critical feedback is offered to students based on their responses.

Second, Taylor, Magleby, Todd, and Parkinson have developed the concept of a faculty or expert coach for student design teams⁸. Rather than a traditional faculty role, the instructor plays the part of a design team coach. In this case, the faculty coach is a

mentor, mediator, and facilitator for teams, providing support, insight, and guiding the way forward. In some instances, other design coaches, such as industry representatives assist teams. An initial training is offered to these individuals to help them with this position. Their role remains the same however, to be a mentor, mediator, and facilitator of design teams.

Third, Brinkman and van der Geest discussed how communication instructors work with engineering design faculty to teach and assess technical writing⁹. Communication faculty developed three tiers of technical writing and supporting criteria: text craftsmanship, genre competence, and strategic communicative competence. Faculty conduct formal teaching during the first few class sessions and then move to the role of coach, providing formal and informal feedback on technical writing to individuals and teams. The authors argue that this kind of feedback is essential for students to fully understand the target and their performance relative to the standard. In addition, the authors further argue that when clear, appropriate feedback is provided, increased motivation on the part of students is likely to occur.

What distinguishes these assessments and processes is the continuous, dynamic nature of the feedback provided to students. These assessments are not summative judgments of student work. The feedback is responsive to students' immediate needs for understanding, allowing corrective action on the part of a student. The assessments are developmental in that they are designed to enhance a student's professional growth in design work. The assessments are generally qualitative, describing student performance in real-time and doing so with an appreciation of the end product. In short, the assessments work to identify the gap between a student's current understanding and performance, and the ideal.

Concluding Remarks

The importance of doing classroom assessment well has gained traction in the K-12 literature in recent years^{10,11}. These works provide empirical evidence for increased student achievement and academic well-being when classroom assessment is implemented in a thoughtful, sensitive manner. The recent report by the National Research Council underscores the positive role formative classroom assessment can play in education more broadly. Given the focus on reform and the concern for increased student achievement in engineering education, this may be an opportune time for engineering education to consider the importance of formative classroom assessment and find ways to implement these strategies in capstone courses.

In addition to the examples described in this paper, Sadler offers the beginnings of an assessment framework that could inform further research and development of formative classroom assessment in capstone engineering education courses¹². Sadler argues for the importance of feedback in the pursuit of student achievement. In this case, formative classroom assessment can provide feedback to instructors about the appropriateness of the curriculum and instruction. When developed and used effectively, formative

classroom assessment can provide feedback to students about their current performance and by implication, what they must do to close the gap between this performance and the instructor's expectations.

This study sought to understand the thinking and use of classroom assessment in the context of engineering capstone design courses through the published literature. Relevant journals and conference proceedings over a 10 year period were queried. Three articles provide detailed illustrations of formative classroom assessment strategies that could be implemented in capstone design courses.

We are currently developing assessment tools for capstone engineering courses with these strategies in mind. Our goal is to develop tools that will enable instructors to provide formative assessments that have the potential of benefiting the student, the project and the course itself.

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