Capstone Design CONFERENCE 2022
JUNE 6–8, 2022 ▸ DALLAS, TEXAS

Formative and Summative Assessment in Senior Capstone Design Courses

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Keywords: Assessment, Capstone Design, Senior Design

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Senior Capstone Design Courses

Senior capstone design courses provide a learning experience for undergraduate students that typically synthesizes content knowledge from their degree and often incorporates exposure to industry practice through client partnerships. Howe and Goldberg write that "although capstone design courses are common across engineering programs, they vary substantially in the way they are implemented"[1]. The first large-scale survey of capstone engineering courses was conducted by Todd et al. in 1995 [2]. They showed that in 1995, 48% of reporting universities delivered lectures in parallel to a design project, 28% held a lecture course before students completed a project, and 74% did not include any lecture component. Compared to 1995, Howe and Goldberg report that in 2019 the delivery of capstone courses with lecture and project in parallel has increased to 68%[1]. Further, Todd et al. report that in 1995, 45% delivered capstone in a single semester whereas 36% percent delivered it over two semesters[2]. In comparison, Howe and Goldberg's results show that capstone delivery over two semesters has increased to 54%[1]. Clearly, there has been shift towards a two-semester capstone with a project parallel to lecture content.

Some research has focused on capstone courses in specific disciplines such as chemical engineering[3] or mechanical engineering[4]. Others have explored the benefits of multidisciplinary capstone courses across disciplines broadly, where multidisciplinary capstone teams have been shown to out-perform monodisciplinary teams through measures of utility, communication skills, and technical analysis[5]. Whether senior capstone design courses are delivered in one or two semesters, with or without lecture, in parallel or sequentially, questions remain about what exactly students are learning in these courses and how learning outcomes are explicitly being measured.

To understand assessment in capstone design, McKenzie et al. conducted a study with two phases: a broad survey focused on assessment of ABET criteria followed by interviews[6]. They found that ABET criteria were generally not well assessed and that faculty had concerns about assessment practices and mismeasurement of student achievement in their capstone design courses[6]. Of key importance, they found that most faculty interviewed had little to no formal assessment training but showed interest in improving their assessment practices[6]. These observations reveal an opportunity to formalize an assessment approach for senior capstone design courses that is grounded in educational theory. A formalized assessment approach can guide best-practices for future refinements that help ensure universities are able to explicitly evaluate learning outcomes for their students.

In this paper, we draw attention to a potential student learning deficit in capstone design courses that stems from a lack of opportunity to learn from instructor, client, or peer feedback. Given that these courses are typically delivered with lecture and project in parallel over two semesters, these courses may not be structured in a way that allows feedback to facilitate learning. We argue that students do not get the chance to apply what they learn from formative feedback to their design projects since students typically complete a single project swiftly progressing through the design process. Through a structured educational approach incorporating intentional formative and summative assessment, we assert that student learning in capstone design courses can be enhanced and explicitly measured.

Formative and Summative Assessment in Capstone Design

In all forms of education, formative and summative assessments are integral for scaffolded student learning and measurement of student achievement. Formative assessment has been defined as "the process used by teachers and students to recognize and respond to student learning in order to enhance that learning, during the learning"[7] and summative assessment has been defined as "the recording of the overall achievement of a pupil in a systematic way"[8].

In senior capstone design courses, feedback from the instructors, clients, and peers can be considered formative assessment, whereas final project reports, physical project deliverables, and project presentations can be considered

summative assessment. Are formative assessment methods in this framework really serving an educational function if students do not have an opportunity to apply the design feedback received to the design process? Since students typically work on a project continuously and with steady progression for two semesters, pressure from instructors and clients to focus on the final deliverable can negatively affect educational value. This also questions the validity of summative assessment in this context. Are the examples given for summative assessment in capstone courses measuring students' ability to apply domain knowledge to the design process, or instead measuring oral presentation skills, ability to write reports, and adherence to project requirements? If the latter is the case, there may be different approaches to capstone design that provide opportunities to apply what students have learned from formative assessments to the design process. In turn, a different approach can lead to summative assessments that appropriately measure students' ability to apply what they have learned over the course of a bachelor's degree to the design process.

A Proposed Approach to Capstone Design

We propose an adjustment to the typical approach to capstone design. During the first semester, students should all work on the same design problem coupled with lecture content on the design process, requirement identification, project management, and so on. This single project can be chosen by instructors to target specific learning outcomes. By having students work on the same problem, the feedback received through formative assessment will be comparative in nature. Students will be able to reflect on how their design decisions impact the overall design process through peer review, gallery style showcases, and weekly design reviews. Metacognitive assignments during this first semester can facilitate learning by having them reflect on their design decisions and their decision-making rationale. Summative assessment should include measurement of design process principles, presentation quality, and communication skills. In practical terms, this first semester also provides students with a completed design project to put on their resumes when applying for jobs at the end of their degree program, which cannot be understated.

In the second semester, students can then apply what they learned about the design process to a project with client partnership. Formative assessment in this semester should focus on project deliverables, peer review, and managing their client relationship. Metacognitive assignments should compare how their approach to design has changed from the first semester with their newly learned skills and with client involvement. Summative assessment should evaluate ability to work with their industry client, apply design principles, leverage content knowledge, and present the results of their design project. This second semester also helps students build their industry network, potentially leading to jobs, and helps avoid the pitfall of students serving as cheap labor for industry project development.

This proposed approach focuses on design principles and project management skills through a structured educational process in the first semester. The second semester focuses on industry exposure by working with a client and the application of design principles to solve real-world engineering problems. We argue that this scaffolded approach will better prepare students for their career after graduation and offers departments an opportunity to explicitly measure learning outcomes from their senior capstone design courses.

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