Assessment and Evaluation Challenges at the Program and Student Levels Associated with Capstone Design

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Capstone Design is a challenge in a number of areas, including assessment and valuation. With ABET's current emphasis on measuring the achievement of Student Outcomes, many programs rely heavily on the capstone design course to assess and evaluate outcomes performance. This form of a program-centered nature of capstone design courses can conflict with a student-centered emphasis within capstone design courses. Similar conflicts can exist in capstone design courses that are process-focused as opposed to being project-focused. A third form of conflict can manifest itself in the realm of balancing team assessment and evaluations with assigning individual student grades. This paper explores these three areas of potential conflict in capstone design courses and the resulting compromises that result when their resolution is optimized. A list of best practices associated with assessing and evaluating student performance in capstone design is presented to extend the dialog on measuring student performance in capstone design courses.

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Introduction

The concept of conflict resolution and the resulting compromise tends to be a sub-theme to Capstone Design Courses that has been comically represented in perspectives on aircraft design[i] and project management[ii]. As evidenced by the utility of the Leatherman and the Swiss Army Knife, finding the optimum balance between competing interests determines a tool's overall effectiveness. Such is the case with the contents and the related assessment processes of capstone design courses.

Howe's 2010 nationwide survey of capstone design courses examined a range of conflicting perspectives for a variety of course factors including how capstone should be taught (lecture, lab or combination), its duration (single or multiple semesters/quarters), project sources, course contents, the number of students per team, as well as a number of other attributes[1]. The survey also examined evaluation in capstone design and the weight of the evaluations (of individual deliverables, group deliverables, final product, and perspectives of other team members) used to determine project and student grades**.**

Methods to Resolve Capstone Design Conflicts

The concept of identifying and resolving conflicts can be applied to the structure of the capstone course as well, with the resolution of such conflicts then playing a key role in establishing all components of the design course. Various perspectives on capstone design can result by simply examining the purpose of the capstone design course. For example, one perspective of capstone design is the realization that the course is "not about acquisition of new abilities, but rather a clinical demonstration of ability that will be applied to professional practice."

This perspective is student-focused, with the resulting course contents and assessment system focusing on the demonstration of student skills. Applying this perspective, Schmidt and Conrad suggest a series of course deliverables that include a statement of work, requirements document, project plan, conceptual design presentation, interim report, bi-weekly progress reports, prototype demonstration, project notebooks, and a final report[2].

Another perspective on the purpose of capstone design courses is a program view of the role of capstone design. Such a perspective may favor using the capstone design course as a key component in measuring the attainment of ABET's student outcomes. It is likely that the structure of the course that supports this need might be very different from the structure that results from other perspectives.

For example, the course contents and the associated grading system from a programmed-focused course would likely be very different from that in a student-focused capstone design course. Wilczynski and Foley describe a collection of capstone design course deliverables that are specifically mapped to ABET's student outcomes, noting that the course itself is

structured around the demonstration of the prescribed outcomes[3].

This topic of different viewpoints promotes a discussion on which perspective is most appropriate for a given course. As with all things, a blended solution (i.e., a compromise of the extreme perspectives) may be the preferable solution for most programs.

Another example of potential conflict within capstone design courses arises when you compare the structure of a product-focused course[4] (where the end goal of a documented and tested solution is emphasized) to the structure in a process-focused course[3] (where the elements of the design process are emphasized and applied to arrive at a solution). Ideally, both the product and the process would receive an ample amount of attention in the course and the related assessment deliverables, but time limitations in a program's capstone design course (or course sequence) dictate the extent that each aspect is emphasized.

One final example of potential conflict in capstone design courses centers on the topics of assessment and evaluation. One perspective is to evaluate the team's project as a whole[iii] with the supporting assessment processes most likely being team-written reports and group presentations during the concept/prototype/final product reviews[4]. Countering the concept of team-based assessment and evaluation processes are processes that focus on individual students.

An extreme measure of individual assessment and evaluation in capstone design is the use of an exam format to measure the design capabilities of individual students[5]. As with the individual versus program and the product-focused versus process-focused perspectives, the team-based versus individual-based assessment and evaluation perspective has potential to dramatically influence the required deliverables and the associated student learning experience in capstone design courses.

Many courses in fact combine the team and individual student assessment and evaluation perspectives and often include a means to apply student input regarding the contributions of their teammates as an evaluation component. In a course that applies a hybrid assessment/evaluation methodology for team and individual performance, specific deliverables are required from individual students and other deliverables are required (and evaluated) as a team's single contribution with the grade for that assignment assigned to all group members.

In this combined assessment method the selection of course deliverables molds the student learning experience, so the system that scores and later combines team and individual deliverables needs to be carefully determined and clearly explained in the course syllabus (and/or course web site). Subjective factors such as the fair distribution of team responsibilities, determining the extent that individuals (for example, those who don't contribute fully to the project) reap the benefits of the team's success, and accounting for superior individual performance (such as that from an individual on an otherwise lackluster team) all complicate the assignment of individual course grades.

Team and Individual Student Grading Algorithms

A few models are noteworthy for grading algorithms that balance individual and team contributions. An MIT course (that in essence fulfills the purpose of a capstone design course[iv]) has a 10-part evaluation system that allocates up to 30% of the grade based on individual performance, with the remainder based on the team's performance[6].

The BYU ME capstone design course emphasizes that "Capstone is not just a class to complete a sponsored design project. Capstone is a class to learn a design process and to learn to apply the design process to a sponsored research project." The grading system used at BYU reflects this dual purpose and evaluates work from throughout the semester based on a series of team and individual grades. A student's final grade is scaled by a multiplier that reflects the individual's contributions relative to the team's performance[7].

It is noted that both cited examples of combined team and individual grading methods, as well as the majority of team-based evaluations reported on by Howe, include a provision to solicit input from individuals on the contributions made by their teammates. The concept of a "fixed pie" is commonly used where contribution portions can be assigned to each member but the total allotment of participation contributions is limited.

It is also common to solicit this type of feedback periodically during the course, with the final peer review then used as a factor in the assigned course grade. Of note is an online peer review process that has been applied in some capstone design courses[8]. The described online process is one that ensures anonymity of the submitted peer evaluations. In addition, the online aspect of this approach is a technique that easily scales to accommodate capstone design courses with large enrollments.

Balancing Perspectives

It is proposed that an effective capstone design course can be created that balances the presented conflicts of student/program focus, product/process emphasis and team/individual assessment/evaluation with the course contents and deliverables properly tuned to these balanced factors. A review of the common assessment and evaluation attributes presented in the noted references offers insight into techniques that serve as best practices for assessing and evaluating performance in a capstone design course.

Included in this list of best practices are:

- Requiring individual and team deliverables.
- Assigning deliverables based on the course duration.
- Distributing deliverables across the semester.
- Establishing and using grading rubrics for individual and team contributions to the project.
- Using deliverables to provide project feedback.
- Instituting systems for peer review within each design team.
- Establishing separate venues to assess and evaluate communication skills and design skills.
- Using a project binder to archive information.

Each of these best practices is described in the following paragraphs.

A ***combination of individual deliverables and team deliverables*** is favored, with the suggestion that some team assignments can be subdivided into sub-team responsibilities/deliverables to increase the granularity on individual contributions. For example, instead of a single team deliverable on risk assessment, requiring two separate deliverables (one from each half of the team) can help identify the leading contributors (for example, should certain individuals always be on a sub-team that submits superior work).

The ***format of course deliverables tends to be influenced by the duration of the course***. Typically multi-semester courses require more written reports (perhaps associated with each phase of the design process as a mechanism to record design decisions over a long period of time) while single semester capstone design courses often rely on project presentations as a means to measure (and provide feedback on) progress. Requiring individual design notebooks (which record all work completed by each member of the class) is a common technique that is used to quantify individual contributions to the team's overall effort.

While the final artifact of the completed design is important, the design process is generally considered as the key aspect of capstone design. As such, ***assessment and evaluation methods should be distributed across the entire semester*** and not be solely determined by a review of the final product. There is, of course, a role in the assessment and evaluation of the final product, but it must be one of many assessment and evaluation factors.

Clear grading algorithms should be established and adhered to, with regular feedback provided to individuals and teams. Providing direct feedback to individual team members is an element of grading that needs to be emphasized. Individual feedback can tend to be neglected in grading processes that center on the design, fabrication and testing aspects of the team's product. Distinguishing between individual and team grades is an important element when reviewing capstone design assignments and projects. These forms of formative assessment can improve student learning and can be used as an extended (and documented) mechanism to deliver design guidance to individual students.

For example, design reviews whether at the concept, prototype, preliminary or detailed design phases, or calendar-based (such as biweekly design reviews) provide assessment and evaluation opportunities to record performance and ***provide feedback for the next phase of the project***. Rubrics are often used to establish norms and especially so when a large number of individuals are involved in the assessment and evaluation process.

Peer review is a valuable component of the assessment and evaluation process, though the concept of peer review requires close monitoring and control. The most successful forms of peer review are tiered, with the initial review only provided to the individual students, subsequent reviews shared with the instructor and student, and the last review used as a factor in determining individual grades. This structure allows the peer review process to be used as a counseling and motivational tool while also serving as a mechanism to gauge individual contributions to the team's project.

Differentiating between assessing and evaluating communication skills and design skills is suggested as a mechanism that provides a fair (as opposed to a lumped) assessment and evaluation of each skill. For example, it is proposed that the "final presentation" be assessed and evaluated primarily as a communications exercise. A separate technical design review can also be scheduled to assess and evaluate the final product's achievement of previously established goals and specifications.

Requiring distinct sessions to assess and evaluate communications and design skills ensures a proper balance between style and substance for a project's final result. Typically the final presentation is a public event that not only concludes the semester but also celebrates the students' work. The technical design review allows time to look closely at the engineering fundamentals of the project and to review details that may not be well suited to a public presentation of the overall project.

Documenting the collective work in a project binder ensures that an archived record of the project is collected and available as examples for later projects and/or as an artifact for visiting program reviewers and/or new capstone design instructors. The project binder format should be prescribed in advance and should include all submitted material including reports, presentation slides, project plans, drawings, schematics and operational instructions.

The project binder proposed is a physical collection of material to serve as an historical record. It is suggested that the physical record be augmented with an electronic record of additional information that is accessible to those associated with the course. To be

most useful, the archived electronic files must be stored in categorized folders, with each file appropriately named and dated to ease information retrieval by a future user who may not be intimately familiar with all aspects of the project. In addition to serving as a reference tool for later access, online documentation is also essential to manage team-based design projects in real time (for team members and design consultants).

Recommendations

The reflections in this paper are provided to highlight the fact that the many demands on capstone design courses not only determine the focus of a particular course, but also impact the deliverables that are required within each course. A set of deliverables assembled for one version of a capstone design course need not be the best set of assignments for another version of a capstone design course. As such, the course emphasis, syllabus and assignments need to be planned concurrently to provide a comprehensive and supportive learning process.

The discussion provided in this paper is not intended as a panacea for all capstone design courses, but rather as a forum to promote best practices that can be improved upon and applied in future capstone design courses.

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[i] As represented in "Dream Airplanes" by C.W. Miller in *Fundamentals of Aircraft Design*, by L.M. Nicolai.

[ii] Detailed at www.businessballs.com/treeswing.htm with additional variations at www.projectcartoon.com/ .

[iii] For the purposes of this review, it is assumed that all capstone design projects are completed by teams.

[iv] As with some other programs, the MIT ME Department does not consider any single course as the "capstone course." A number of project based design courses effectively serve as the capstone design course, including MIT's 2.009 course Product Engineering Processes.