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Creating and Sustaining High-Quality Senior Capstone Experiences

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Abstract

The 2011 Outcomes Assessment Model for accreditation by the Association of Technology, Management, and Applied Engineering (ATMAE) requires coursework in both management and technical areas of technology, with a “reasonable balance” between the practical application of “how” and more conceptual application of “why” (ATMAE Outcomes Assessment Model, 2013). One way to meet this requirement is with a senior capstone course. Capstone courses focus on the integration and application of technical skills and knowledge along with consideration of multiple realistic constraints. A high quality capstone experience has many positive outcomes for the student, faculty, and department. However, capstone courses can be challenging for both students and faculty.

Disciplines

Agriculture | Bioresource and Agricultural Engineering | Engineering Education | Higher Education and Teaching

Teaching Innovations

Creating and Sustaining High-Quality Senior Capstone Experiences

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Introduction

The 2011 Outcomes Assessment Model for accreditation by the Association of Technology, Management, and Applied Engineering (ATMAE) requires coursework in both management and technical areas of technology, with a "reasonable balance" between the practical application of "how" and more conceptual application of "why" (ATMAE Outcomes Assessment Model, 2013). One way to meet this requirement is with a senior capstone course. Capstone courses focus on the integration and application of technical skills and knowledge along with consideration of multiple realistic constraints. A high quality capstone experience has many positive outcomes for the student, faculty, and department. However, capstone courses can be challenging for both students and faculty.

This paper will outline the challenges and best practices learned in the development and implementation of a senior-level capstone course with technology undergraduates. Specifically, strategies for sourcing student projects, student team formation and management, and options for ensuring accountability among student teams will be discussed.

Senior Capstone Courses

Although capstone courses are an important part of the engineering and engineering technology curriculum, the course structure and format varies widely across educational institutions and degree programs (Pembridge & Paretti, 2010). The emphasis of capstone courses generally give students the opportunity to apply technical tools, techniques and knowledge learned in the classroom to an open-ended, realistic, and creative problem-solving experience (Friesen & Taylor, 2007). The senior capstone course is a fitting experience for graduating seniors in engineering technology as it gives broad exposure to the 4 Pillars of Manufacturing body of knowledge, identified by ATMAE, ABET, and other organizations as the primary quality improvement tool in manufacturing engineering and technology degree programs (Society of Manufacturing Engineers, 2012).

The capstone experience described in this paper is part of an engineering technology program in an agricultural and biosystems engineering department. The department includes four majors: two engineering programs accredited by ABET and two technology degree programs, accredited by ATMAE. The author leads one of two sections of senior capstone courses in engineering technology (which includes the majors of agricultural systems technology and industrial technology) offered by the department. Technology students complete the required two-course sequence in the final year of their baccalaureate degree programs. Teams of three to four students work industry-sponsored projects that are assigned in the middle of the first semester and completed by the end of the second semester.

Historically, the number of students enrolled was approximately 20 students per semester. The author has taught the course for four years, but in that time the enrollment has increased dramatically, as shown in Figure 1.

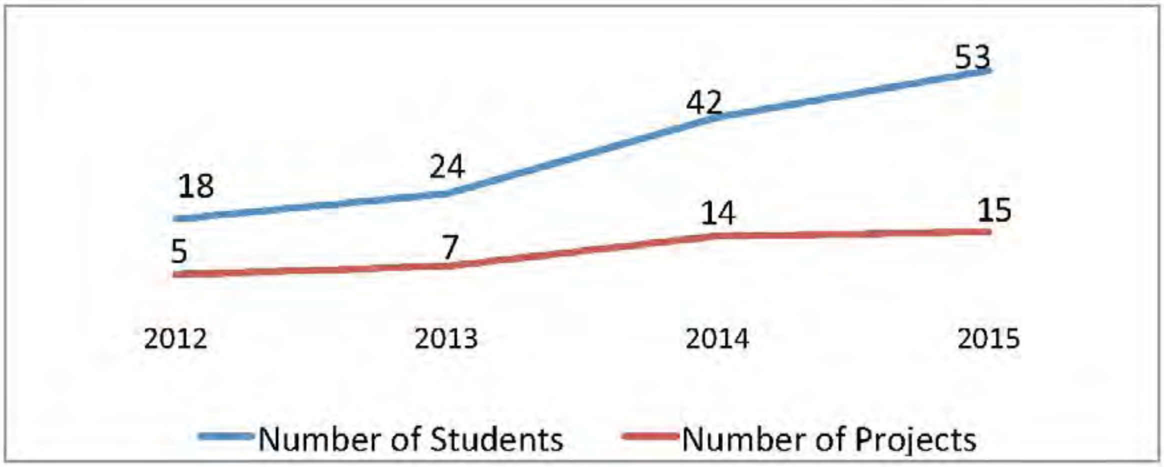

Figure 1. Number of capstone students and projects: 2012 through 2015

Increased enrollments have influenced the way the senior capstone course is taught, but the overriding goal is to keep the hands-on, problem-solving nature of the course, even when the number of students and projects is larger than in the past.

Industry Projects

The use of industry-sponsored projects is the tradition in the author's department. Although the "real-life" aspects of industry-sponsored projects appeal to both faculty and students, these types of projects have both advantages and disadvantages. Advantages to industry-sponsored projects include: students can work a realistic problem, financial support from industrial partner is generally available, student motivation is often higher, and faculty have the opportunity to observe students working in non-academic environments (Magleby et al., 2001; Friesen & Taylor, 2007). Industry-sponsored projects also facilitate outreach from the academic department to industrial stakeholders and provide the mechanism for external and expert opinion needed to validate student learning, as required by many accreditation bodies.

However, industry-sponsored projects also have negative aspects. These include: challenges to sourcing and recruiting students projects, risk of failure has higher stakes, faculty often must work outside of their expertise area, and intellectual property and other administrative issues must be resolved between the academic institution and the industrial partner (Magleby et al., 2001; Friesen & Taylor, 2007). Even with the potential negatives listed here, previous researchers have found that the majority of capstone courses taught in engineering fields utilize industry-sponsored projects (Todd et al., 1993; Howe & Wilbarger, 2005).

To address the issues identified by previous educators concerning the use of industry-sponsored capstone projects, several actions have been taken at the program, department, and college level. The first of these is a project form. The project form describes the engineering technology capstone program to potential clients and helps guide the thought process of industrial sponsors on project development. The form is circulated among external stakeholders and clients. In addition, when contact is made with the University's service unit for short-term projects, the form is sent to prospective clients, who in turn complete the form with a potential project idea or ideas. Project concepts are submitted to the faculty leading the capstone course. He or she will then vet the projects and present the resulting project ideas to the students for consideration and eventual selection.

The use of the project form addresses several challenges identified by the National Academy of Engineering in 2012. First, all projects are vetted by the instructor or instructors before being accepted as a potential capstone project. This allows for projects to be appropriately scaled for the time period allowed, which is one area of challenge identified by the National Academy of Engineering in their 2012 best practices report.

A second advantage of the project forms is that they require prospective clients to think about the scope of the project before agreeing to participate in the capstone course. Early planning and engagement of industry partners at the beginning of the capstone process is also recommended by the National Academy of Engineering (2012). In this case, project forms are distributed to potential industrial partners at every possible opportunity, including to groups such as the alumni association, the departmental advisory council, and other external units. Project ideas are accepted from prospective clients 12 months a year, and efforts are made to develop relationships with industrial partners that go beyond a one-time course project.

A third advantage of the project forms is that they identify key contact person at each company where projects take place. As suggested by Magleby et al. (2001), the forms allow the instructor to review the project to ensure it is a good fit with University policies, timelines, and resources. Additionally, concerns with intellectual property and liability can be addressed up-front rather than in the middle of the project.

Lastly, the project forms facilitate a strong and structured administration and communication plan between the industrial client and the university. Friesen and Taylor (2007) identify this as a key component for the success of university and industry collaborations. These recommendations also reflect earlier conclusions by Todd, Sorensen, and Magleby (1993) on the design of capstone projects for industrial clients.

Student Team Formation and Project Selection

A second challenge of capstone courses is that the majority of courses are taught using student learning teams (Shuman et al., 2005; Dym et al., 2005). Team selection has been discussed by previous researchers (Pembridge & Paretti, 2010; Dym et al., 2005; Bacon et al., 1999), specifically in terms of most positive classroom outcomes. Although each method has its advantages in certain environments, for long-term projects that have high stakes (as is the case with capstone projects), instructor-selected teams are the recommended method of team selection. To assist with the difficult task of assigning students to teams and then assigning the teams to projects, a method was developed for use in the capstone classroom (Mosher, 2014).

Early in the semester, students must complete a learning styles survey. This activity is more for the students' benefit than for the instructor - students often do not understand how they best learn and this activity gives them a chance to think about and reflect upon on their preferred learning style. Students also complete a detailed form where they identify which courses they have taken, what project management activities they enjoy, and how they handle deadlines and large projects. In class, work styles and project management concepts are discussed and students are prepped for the project assignment process.

As part of the project and team assignment process, students are required to submit a written "bid" that outlines the top three projects they are most interested in completing for their senior capstone project. Information on the projects, the clients, and project background and requirements are presented to the class by the instructor earlier in the semester. Students are required to explain their background and working style and how these skills and abilities would support their work on a specific project. Students may select more than three projects if they wish. They may also explain which projects they would rather not work on.

As part of the written bid assignment, students are allowed to indicate fellow classmates they would like to have as teammates. Students may also identify classmates they would prefer not to work with. Although it is not always possible to honor every request to work with a specific classmate, requests to not work with a certain classmate are always honored. As shown in Table 1, most of the students did not indicate a specific person to work with or not work with. Therefore, student preferences and ultimate assignments were driven almost entirely by their project requests.

Table 1. Student project selection process data for 2014* and 2015**

Action	Met	Not met
Specific teammate request	9 (2014) 20 (2015)	6 (2014) 7 (2015)
Teammate Non-request (requesting to not work with someone)	12 (2014) 9 (2015)	0 (2014) 0 (2015)
Assigned to one of top 3 project choices	41 (2014) 52 (2015)	1 (2014) 1 (2015)

*n=42 total students; **n=53 total students

The entire process for project and team selections lasted approximately three weeks. Although the process of assigning teams and projects closely resembled putting a gigantic jigsaw puzzle together from an instructor standpoint, the final outcome has been very positively received by students. While students have some say in whom they work with and which capstone project they work, the instructor makes the final selection. The process also is inclusive for students who may not have friends or acquaintances in the course. All students receive a project that they already feel some ownership and connection with.

Ensuring Accountability of Students

Fair and consistent assessment of students is always challenging, but the capstone course adds even further challenges (Dutson et al., 1997; Brackin et al., 2011). The evaluation criteria of capstone courses include multiple aspects, some of which cannot be controlled by students or faculty. Brackin et al. (2011) argue that a failed capstone project does not always mean that no learning has occurred. For this reason, evaluating a project simply on its "success" as perceived by the instructor is not always the best practice. Ensuring individual accountability on student teams is also a challenge (Bacon et al., 1999).

Integrating team activities while keeping individual accountability can be facilitated through peer evaluation (Freeman & Dyrenfurth, 2004). The basis for peer evaluation is to counteract the tendency toward "social loafing" – a phenomenon that occurs when individuals lower their effort when working in a team, assuming that other members will pick up their work tasks (Bacon et al., 1999). Michaelsen et al. (2004) suggest that a single peer evaluation is not as effective as multiple evaluations that occur throughout the course. Peer evaluation provides team members the ability to indirectly address low performers on their team. Poor team performance, even of a temporary nature, will negatively impact the grade in this case, as the peer evaluation scores given by teammates constitute approximately 25% of the final grade.

A second way to enhance individual accountability is by using low-stakes assignments (Elbow & Sorcinelli, 2011). In this course, students are required to individually submit a "memo" to their instructor after each instructor and team meeting, summarizing the meeting highlights. Instructor and team meetings occur approximately every two weeks. By providing a synopsis of the content covered in the meeting, students accomplish two tasks: 1) forced record-keeping on project details and 2) providing an indication of accountability for both attending and remaining engaged during the instructor/student meeting. The assignment also gives students the opportunity to summarize what they perceive as the important components of the meeting – completing the learning competencies of evaluation and synopsis – both of which are at the highest levels of Bloom's Taxonomy (Bloom, 1969). The individual meeting synopses comprise approximately 25% of the final grade.

Together with the peer evaluation scores, nearly 50% of the grade is based on individual contributions and the quality of team contributions. A third component of team projects is the management of conflict (Brackin et al, 2011). Remembering that students generally do not have the skills to remediate major conflict within their team, effective mentoring from the instructor is important. For this reason, providing a clear path for expectations and the structure of the course assists students and provides the basis for actions taken by the instructor in response to low student performance.

Implications for Technology Faculty

The use of capstone courses in technology degree programs has many benefits, but adding a capstone course to the degree program can be challenging. The overriding goal of capstone course projects is student learning and this must drive all decision choices regarding project selection, management, and evaluation. A failed project does not necessarily mean that no learning occurred, however, a challenging but positive experience provides benefits to all parties.

The following are primary considerations for faculty in developing and leading a high-quality capstone course for technology undergraduates:

- Appropriate scoping and planning of the project with the client ahead of time
- Ownership and buy-in from students through controlled project and team selection
- High tolerance for ambiguity and uncertainty as students work through the details of the project
- Balanced methods of individual and group accountability

Although leading a capstone course can be challenging, it can also be very rewarding for students, faculty, and industrial clients and remains one of the best ways to evaluate how well students have learned to apply the technical content they have been taught.

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