Professional Career Skills in Senior Capstone Design

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A one credit hour fall seminar course allows many preparatory topics to be engaged by the senior capstone teams which makes the spring laboratory portion of the course run more smoothly. Topics such as team building, oral and written communication skills, and organizational interaction are integrated into the course sequence before the students perform the physical work, reducing issues during the lab component.

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Introduction

The undergraduate education programs of the Purdue University Agricultural and Biological Engineering (ABE) program are highly regarded.[1] These students are well sought-after by the department's industrial partners, and the greater majority of seniors seeking employment have secured positions within a few months of graduation. The faculty and staff of the department believe that the Senior Capstone Design sequence is one of the primary reasons for the successful integration of Purdue ABE students into entry-level professional positions.

The capstone focus within Purdue ABE is on the preparation for career success by training the students in project management skills and effective project execution. The capstone experience in ABE was introduced as an optional projects class in the mid-1970's, and it has evolved into a required two course sequence that initially concentrates on the design process and then transitions to an actual project laboratory with specific technical goals. All engineering students (~75/yr) and Agricultural Systems Management (ASM) students (~50/yr) are required to take this sequence to graduate. The department typically has around 30 teams per year averaging about three team members. Students are expected to invest about 5 hours per week outside of class during the fall and 20 hours during the spring. Industrial project sponsors are not charged a participation fee, but they are expected to meet the required costs of the work. Internal project are generally limited to $500 total cost. The courses are generally well-regarded by the students in both the university mandated evaluations and the graduating senior exit interviews conducted by the department chairman.

The purpose of this paper is to relay the specific experiences of the Purdue ABE faculty in conducting and administering the capstone course sequence, and it is intended for other faculty members in higher education that either do or will be teaching similar classes. This paper will relay the design of the Purdue ABE experience; discuss project solicitation, team selection, and academic topic coverage, including the presentation of successful professional life skills; examine the expected deliverables from the student teams; and cover the feedback provided by our students and external reviewers.

Course Design

The titles and protocols for the two courses vary slightly by academic major. ASM students typically take 'Project Planning and Management' in the fall and 'Capstone Project' in the spring. Engineering students typically take 'Project Planning and Management' in the fall and 'Agricultural Engineering Design' in the spring. Biological Engineering students, which include Food Process Engineering students, meet separately from the balance of the seniors, but they participate in the same unified department-wide presentation and final evaluation process. ASM, Environmental and Natural Resource Engineering, and traditional Agricultural Engineering students meet together. The fall course may be considered a lecture / seminar class, and the spring course is a project laboratory experience. Engineering students that have December graduations utilize a single combined course, 'Agricultural Engineering Project Management and Design', that meets in the fall and matches the work load of the two course sequence. ASM students do not typically get out-of-sequence, but those that do are allowed a 'Special Topics' class registration, which the ABE academic affairs committee approves for substitution in the student's academic record on an individual basis.

The fall seminar class is a one credit hour course with the following global learning objectives:

- Identify strategic project objectives and key tasks associated with specific objective completion;

- Plan the timeline and details of a medium project;
- Plan the budget and financial details of an intermediate term project;
- Provide informal progress updates to mentors and instructors regarding project progress;
- Interface and seek project sponsors guidance;
- Understand the concepts of professionalism, ethical responsibility, and integrity when applied to technical projects;
- Enhance written communication skills through the production of a comprehensive project proposal;
- Enhance oral communication skills through the production of a proposal summary presentation;
- Learn how to respond to questions and criticism; and
- Understand the concepts of deadline, closure, and delivery.

The three hour spring laboratory class retains the above items and adds the following learning objectives:

- Design an environmental and natural resources system or a machine system to solve a specific need;
- Model, prototype, and test project designs within a team environment;
- Learn how to accomplish specific tactical goals for a project within a larger operational environment (i.e. University Machine Shop & Business Office; Corporate Sponsor's Organization); and
- Understand the compromises and load sharing necessary for effective team harmony.

The combined fall course and the improvised special topic course utilize the same global learning objectives as the spring class. Although registration for the engineering students and the ASM students is different, the classes are conducted in a combined manner, with no differentiation between the students. Expectations are the same for everyone enrolled. The course objectives are designed to align with the ABET Criterion 3 (a-k) standards.[2] It is the opinion of the Purdue ABE faculty that these goals are equally valid for our ASM, engineering technology analog majors, as they are for engineering students. The overall goal is to create students that can contribute to society by managing and executing sound technical projects. The capstone experience is designed to provide students with a safe environment to practice on a project that resembles the skill requirements and decision making responsibilities that would be expected of a trained engineering or technology graduate in an entry-level job.

Project Solicitation

The capstone process at Purdue ABE serves multiple purposes for the department and faculty. Foremost is obviously the career preparation of students. This is unquestionably the first goal of the course sequence. However, there are other departmental objectives that have become beneficially entwined into the capstone process. Purdue ABE considers that relationships with the department's corporate partners are an important portion of our collective success. Accordingly, industrial projects are solicited from alumni and long-term corporate contacts for consideration by the students. This process keeps relationships with industry on-going and relevant to the issues that they are contending with. These project sponsors, along with their colleagues, serve as external reviewers for the projects as various times throughout the year. This brings these individuals to campus, allowing them to have personal contact with both the students and faculty. This facilitates employment opportunities for the students and research opportunities for the faculty, and it keeps the industrial partners engaged with activities in the department. The positive feelings and goodwill generated by this activity are of significant intrinsic value to the department.

Purdue University has determined that an overarching strategic goal of students' career performance shall be the positive impact that they have upon the lives of others. In keeping with this philosophy, the department also looks for non-industrial development projects that match the older 'extension' goals of the land grant college mission. These projects generally come from individuals, charity, non-profit, or governmental organizations. As with the industrial projects, alumni and other long term contacts are approached for project abstracts. These individuals and their co-workers are also invited to participate in the external reviews of the student work. Additionally, faculty members within the department and the Purdue College of Agriculture are utilized for projects that have local utility to the institution. Other departments within the College of Engineering typically have their own capstone processes which adequately covers the similar needs of their faculty. Many of the faculty derived projects are legacy projects, research start-ups, or continuing contest entry teams. Participating faculty and staff are encouraged to join in the review process and participate in the on-going evaluation of the students' work. Finally, talented and ambitious students have recently been allowed to propose projects for consideration. These projects are very closely reviewed and must meet the same relevance criteria as solicited projects.

Projects for the coming academic year are actively solicited during the summer months, prior to the start of the fall semester. The instructors' goal for this phase of the process is to have a selection of projects that are of sufficient interest to the students so that there are roughly twice the number of potential projects than can actually be filled. Project abstracts are provided to the students at the first class meeting in the fall, and they are asked to review and select their top five ranked preferences from the

provided list. The instructors select project teams based upon those preferences, the potential project impact, the likelihood of success, and the integration of the project within the larger goals of the department and institution. Over 90% of the students typically receive an assignment to one of their top three choices.

Team Selection Philosophy

In order to more nearly mimic the working world process, the instructors select the projects and the team assignments. The work environment is modeled as closely as possible. Students are assigned to project based upon skill sets and need. Student partnering requests are generally not accommodated, unless there is a rational, valid reason. Where possible, the instructors create mixed teams with both engineering and ASM students. Although there is no quantitative data to support this, it has been a long term qualitative observation of the faculty that the mixed teams are stronger than either all-engineering or all-ASM teams. Rationally, this would seem to make sense, as each variety of student brings unique and complementary skill sets to the team.

Purdue ABE believes that the project teams are larger than just the students. Communication and personal interaction are highly important aspects of the capstone experience from the faculty's perspective. Accordingly, all project sponsors must assign a key contact for the student team members. The undergraduates are required to maintain appropriate contact levels with their sponsor. There are three faculty members which serve as instructors for the Purdue ABE capstone experience. All teams are assigned a specific instructor for on-going contact. In general, one faculty member oversees the Biological Engineering projects, one supervises the Environmental and Natural Resources projects, and a third manages the Machine Systems projects. Finally, all teams are assigned a technical mentor. This is a faculty or staff member with specific expertise in the general area of the project. Student teams are required to continually interact with the sponsors, instructors, and technical mentors. This structure is designed to resemble the active work environment where numerous parties have input and require status updates of specific project progress.

Academic Topic Coverage

The fall course is designed to provide students with an introduction to academic topics specifically related to the management of technical projects. There are 14 available class periods. Two of those sessions are used for oral presentations. The students are excused from the scheduled meeting of Thanksgiving week. The remaining 11 class periods are utilized for instruction. The opening period is an introduction to the course and. Administrative details are covered, and the abstracts of potential projects are presented. Students are asked to respond with their selections by the end of the first week. Any student not providing a preference is warned that the consequence is assignment at the instructors' preference. Project assignments are given during the second course meeting. The expectation for project notebooks is discussed, and three team meetings with the instructors for the fall term are scheduled. These meetings cover a clarification of the project mission and a debriefing for each of the two fall term oral presentations and the written document progress submissions. The weekly team meetings with the instructors for the spring term are scheduled during the first class meeting in January.

The third class meeting covers an overview of project management. A comparison and contrast between project management and the management of continuing operations is used to illustrate key points. Research and the concepts of mission and closure are discussed. The fourth lecture deals with the design process. Two models of the overall creative design process are reviewed.[3] The fifth class meeting covers working within the Purdue environment. The ABE process forces the students to work inside the Purdue system to introduce functioning within a larger organization. Safety, business offices, IT specialists, and communication experts are introduced. The fundamentals of technical writing are discussed during the sixth lecture, and the different types of oral presentations are examined during the seventh. The students make feasibility pitches during the eighth class meeting. This presentation is designed to mimic a semi-formal group meeting within an organization that is designed to select which opportunities are worth pursuing under a limited resource environment.

The ninth class meeting explores project planning, Microsoft Project®, resource allocation, and budgeting. The categories of resources are discussed, along with how to estimate specific needs for a specific project. Team dynamics and personality types are covered in the tenth session. This material is a relatively recent addition to the course material to address the continuing problem of dysfunctional teams. Analytical Psychology[4] and the Myers-Briggs personality tests[5] are introduced to aid students in better understanding fellow team members and how to get along with others in a workplace. The eleventh lecture covers techniques for quantitative and qualitative decision making. The comparison concepts of performance metrics and the Franklin Ledger are introduced. Additionally, material on positive career progression and the characteristic traits of a successful professional are discussed. The twelfth course meeting is used for the presentation of specific team management plans for the spring term. These presentations are given to both internal and external reviewers, and they are supposed to present the groups' plans for the next, applied laboratory phase of the capstone experience. The final class meeting of the fall is used for covering administrative details and preparation for the spring term.

Course Deliverables

The Purdue ABE capstone experience provides the opportunity for project teams to make four separate technical presentations and to create two distinct project documents. Slides for all formal presentations require instructor approval ahead of the talk, and teams are required to make revisions, if their materials are found to be lacking quality. The feasibility pitch presentations have been recently introduced into the sequence midway through the fall course to provide the teams with an opportunity to run through a presentation together, prior to facing external reviewers. The management plan review is conducted at the end of the fall and is the first presentation before external reviewers. These reviewers have traditionally been tougher on the teams than internal reviewers, so this practice presentation has been added to the process to increase the experience and confidence level of the presenters.

A formal technical design review is conducted midway through the spring term. This presentation is given to the same internal and external reviewers. The student teams are expected to have made adjustments based upon earlier comments, but only at this mid-point during the laboratory phase of the sequence are the actual designs finalized enough for effective criticism. The scheduling of these presentations prior to spring break allows time for the teams to make adjustments before the end of the spring class. The final presentation of the Purdue ABE capstone sequence for the students is an elevator pitch about the overall project. This is the larger course closure event, and it is conducted using a project poster document created to describe the experience.

The final project poster is created by the student teams according to a recommended format, and it must be approved by both the instructor and the technical mentor for the project, prior to printing. Teams are provided with the opportunity to have their elevator pitch taped and critiqued before the final presentation function at the end of the spring course. The poster and elevator pitch are judged by both internal and external reviewers to determine first and second place winners within similar sub-groupings of roughly seven teams. The overall experience is celebrated at a year's end banquet for the students and their guests.

Each team is required to produce a single formal written document regarding their capstone project. The teams work on and refine the document throughout the year. This document is presented to the project sponsor at the conclusion of the sequence. A draft of each team's term paper is due roughly at the same time as the oral presentations. An instructor reviews the documents and provides feedback to the teams as the course progresses. The expectations for progress on the document are clearly outlined by the instructors ahead of time, and faculty approved rubrics are used and provided to the students for use in document improvement. Improvement is tracked and used for ABET purposes.

Continuing Improvement and Closure

Purdue ABE has a well-founded culture of continuous improvement in academic offerings within the faculty. Students are polled regarding their opinions of classes, and faculty review data regarding certain outcomes annually. Improvements are discussed and instituted based upon consensus of the individuals directly involved. Those changes are then examined for effectiveness. There have been several modest changes to the Purdue ABE capstone sequence over the last few years to improve the learning outcomes of the students.

In response to external reviewers, specific oral presentation objectives have been clarified, and slide show visual aids now undergo preliminary review. An additional 'practice' presentation has been added to the schedule, and elevator speeches are videotaped and provided to the students for self-review, prior to the final presentation session. The types of oral presentations typically seen in a business environment are now covered in the academic portion of the sequence. Two additional rounds of progress submission review and faculty critique for the written documents have been added to improve the quality of those materials. Academic material covering personalities and motivational strategies has been added to the academic section of the capstone sequence to aid students in understanding how to combat team dysfunctionalities. Review of these modifications is on-going, but anecdotally, it has been noted that long acquainted external reviewers have commented positively on the recent improvements. The students seem happy with the overall experience and comment positively about the capstone sequence in their exit interviews upon graduation. In conclusion, it seems fair to state that the iterative design process taught to Purdue ABE students is practiced by the faculty. Outcomes are evaluated, and the overall process is adjusted to improve the results.

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