Running Capstone Like a Business – Focus on the Client

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Many engineering capstone programs are managed and executed as traditional student projects with academic mentors. In this model, the focus appears to be on the student and not on the outcome but often both suffer. This paper outlines a capstone management model within the Industrial and Manufacturing Systems Engineering Department at Iowa State University where capstone is run as a business with emphasis on the client. In this department 100% of the one semester capstone projects are supported by industry at $5,000. In this model, nearly every project is managed to a successful outcome with students performing the work under close supervision of practicing engineers. The key premise is that students learn how to execute successful engineering projects by performing successful engineering projects, and that clients are willing to participate and fund these projects.

Keywords: Expectations, project scoping, industry relationships, industry value, student value, course deliverables.

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Introduction

In Spring 2014, the IMSE Department was offering a one-semester capstone course where 4 person student teams worked on unique projects within the same client. This meant that one client had to come up with up to 10 projects a semester for students to work on in addition to finding internal staff to manage those projects.

Often those projects were poorly defined and client supported which made for a great variance among scope and deliverables, as well as, client/student value between the teams. Needless to say, it was becoming increasingly difficult to find clients each semester, and several projects did not meet the ABET Design outcomes the department was seeking.

Additionally, the projects were very difficult for faculty to support and assess since the faculty often didn't have the knowledge, skill or involvement of the specific problem that the students were working on, which is also problem reported at other schools.[1]

Beginning in the Fall of 2014, the department embarked on a more client-focused approach involving pre-scoped projects at multiple clients which were closely managed by a consulting engineer hired by the department as a lecturer (Professor of Practice).

The fundamental principle of this approach is that all industry projects need to be successfully executed. This was deemed necessary in order to ensure that clients would want to participate and fund the projects in successive semesters, and that students would learn how to execute a successful engineering project as opposed to sometimes learning how to fail - previously considered a viable alternative.

Finding and Scoping Projects

Initially, it was difficult to come up with the 10 required one-semester projects among 10 different clients for a fee of $1,500 each. The fee, albeit small, was required in order to ensure that the company would take the project seriously, involve management and provide the funds necessary to cover the anticipated travel costs for the students. Once successful results were achieved, most of the companies 70-80% resigned for subsequent semesters. This was critical as student enrollment doubled and the department now conducts 21 to 24 projects each semester for a fee of $5,000 each.

The instructor found the initial projects from:

- Current consulting contacts.
- Department Industrial Advisory Board.
- Engineering Extension Office.

After identification, the instructor then travelled to each company to conduct an on-site assessment and discussion of project options and scope. During this visit projects were selected with a potential economic value of at least $100,000 in 3 year Net Present Value terms. This economic impact was important to justify the desired $5,000 capstone fee (currently charged), to ensure that the company would see obvious value and to engage the students that they were working on an important project. Eventually this economic impact was also valued by the College of Engineering which now

reports the department's capstone project savings as a major part of the College's industry outreach impact.

At this point, the department is also benefiting from industry references which generate new project alternatives that allow the department to be more selective in project approval.

A key component of this approach is that the instructor who manages and assesses the students is the same person who defined the project at the client site prior to the start of class. Dividing this function across multiple people will create substantial problems with successful delivery.

Finally, the instructor ensures that the client's legal department is satisfied with the University created IP and NDA forms which all students and faculty on the project must sign. Since this form is standardized for all clients wishing to work on a project for any student team at Iowa State University, they are not subject for modification and thus can be (but often are not) a project job-stopper.

Team Formation and Assignment

Initially the department was selecting the students into teams, but this new approach demanded that as many teams as possible were formed from students who had a good prior working history in order to minimize factors which could negatively impact project performance.

This approach has worked well, since most students have formed tight bonds by the final semester of their senior year when they take the capstone course. Of course there are still groups formed automatically from those students who chose to be placed into a team. Only around 20% of student teams encounter issues worthy of faculty intervention, and auto-assigned teams do have a modestly disproportionate number of those interventions.

On the first day of class, student teams evaluate the project options available and prioritize the projects from the list. They are required to submit a one-page proposal for their top three choices which is written to convince the instructor why they are the best team for those projects. In addition, students submit their resumes with those proposals.

The instructor reviews this information and attempts to map each team to a project based on that team's ability to achieve the best result for the client. In Fall 2017, 78% of the students received their top 3 choice (38% first choice) and all students received a choice in their top 4. In other semesters only one team had a 5th place choice that was most often assigned because they were the best team for the project but the company was a 3 hour drive away.

Managing the Project

The semester is broken into four deliverables. Each of these deliverables involves a written paper and company presentation. These are:

1. Problem Statement (3 weeks).
2. Current State Analysis (5 weeks)
3. Future State Design (4 weeks)
4. Final Report (3 weeks)

In addition, each student team must create a poster which is presented to faculty, students and industry in an expo on the Friday of Dead Week, and also a 3 minute video which is shared on the departmental YouTube channel (www.tinyurl.com/IMSE-IASTATE) and is designed to contain information fully approved by the client.

During the semester, student teams are required to visit their client physically a minimum of 7 times. ISU's transportation department arranges rental cars for the students paid for by the capstone fee. In addition, students are required to be in verbal contact with their client at least once a week, as the course seeks to remind students that relationships are important and email/texting are not substitutes for effective project communication and reporting.

The course includes three 2-hour lab sessions each week. The instructor sits down with each team for 10-15 minutes during each lab to assist in evaluating progress, offering guidance and sometimes performing a required motivation activity. These regular meetings are crucial to keeping the project on track and the deliverables meaningful. At this point in their career, students simply do not possess the experience necessary to effectively scope, manage or execute a $100K+ engineering project, but they learn quickly and most groups are performing with minimal coaching by the 4th deliverable of the course.

The instructor travels with the students on their mid-semester Current State Analysis presentation where the students' present their analytical findings of the problem and their expected approaches to the design. This is a critical meeting where the course instructor is able to visit the facility again, and personally interact with the client and their team. Decisions made during this CSA meeting allow for scope and deliverable changes which are very common in industrial projects to ensure a successful outcome. In addition, the design deliverable

and presentation is due 3 weeks before the end of the semester to allow students the time necessary to correct any shortcomings with their project before they graduate.

In addition, the instructor is in email or phone contact with each client throughout the semester. The amount of contact depends upon how well the project is going and how well the team is interacting with the client.

Student Results

Student feedback has been nearly unanimously positive. Many students now use their capstone results as part of their resume. In Fall 2014, four students were placed at the companies in which they worked on capstone projects. Since students are working on real projects with actual practicing engineers, faculty finds that students put in additional effort and a commitment to detail not typically seen in semester projects[3].

During the semester, students are required to submit weekly individual log reports which document the 15 hours they are required to invest in the project as well as how they feel about the contribution of other students on their team. Instructors use this information to engage productively in helping address student issues before they become problems which will affect the client.

Student teams are able to dismiss a student member from their team during the semester which results in that student failing the course. So far, all students who were subject to this policy have personally decided to drop the course. This situation has occurred in less than 0.5% of the students.

Student teams are evaluated in a competition at the end of the semester. While Client stated Economic Impact and Percent Implemented are not factors used in assessing students, they are 2 of the 5 factors used in a competition at the end of the semester to select the best capstone project. In this competition the top team receives their name engraved on a plaque prominently displayed in the department and they receive $150 in cash each.

Industry Results

The capstone course regularly achieves a 70% repeat rate with clients offering projects (*Chart 1*). Repeat projects are mainly with mid to large sized firms which always have substantial projects that need to be performed. Small and startup firms typically engage in only one or two projects and return sporadically in subsequent semesters as the need arises. In a few situations, staff changes, or company policy changes have resulted in firms opting-out of future capstone projects. Over the past few semesters the course sizes have grown substantially which is bringing in more first-time clients.

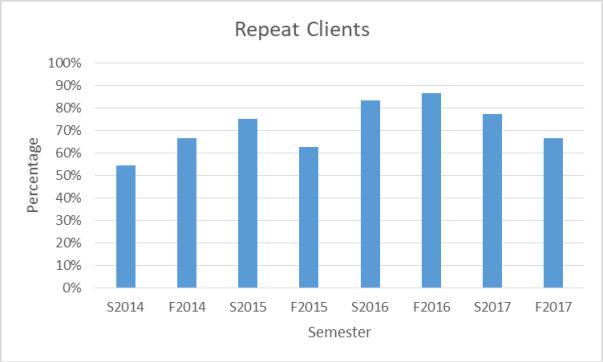

Chart 1: Percent of Companies Participating Again.

Since this process involves considerable up-front time in defining projects, the capstone instructor typically performs many of the visits during the late Spring and Summer months to establish the bulk of the projects for the coming year. Additionally, since the Spring semester is larger than the Fall, companies receiving a Fall project must also commit to one in the Spring. This high-touch project recruitment effort is a requirement for any industry-focused capstone program[2].

At the end of each semester, companies are required to fill out a report listing the percentage of student recommendations that they will implement as well as their assessment of the 3 year Net Present Value of those recommendations. The results have been impressive on both factors (*Chart 2 and 3*).

While the implementation percentages have been high (>80%) from the start, the project economic impacts have grown considerably. This is largely an outcome of the companies picking more challenging projects and working with the students on those projects more effectively. In addition, students are strongly lectured and reminded to ensure that their efforts are focused on those elements of their projects with the greatest economic impact.

Total semester impact in the past four semesters has exceeded $14 million each semester with a peak value of $16.5 million in Fall 2017. Note that these are economic impacts reported by the companies to the university.

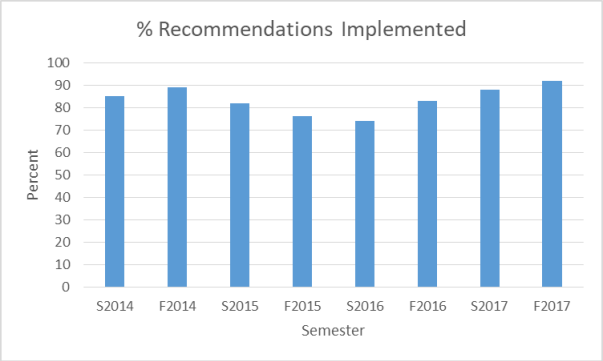

Chart 2: Percent of Recommendations Implemented

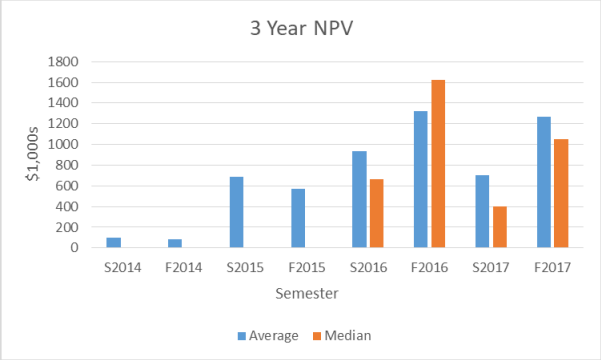

Chart 3: Economic Value Per Project in $1,000's

Faculty and Department Results

Faculty results have been largely positive. Faculty is consulted by the students when working on portions of their projects that require a depth of understanding beyond the capstone instructor and also leverages a particular faculty member's expertise. On the other hand, faculty members are not personally or professionally responsible for the project or the results so the time commitment is typically minimal.

Some faculty members have expressed concern with the commercial or financial focus of these projects and the concentration of effort spent on them relative to social causes or research which could not support the minimal fee. In response, two recent projects for a local Foodbank warehouse design were performed at a reduced fee which was actually paid for by an outside donor. The department is looking for additional ways to externally subsidize socially oriented projects.

Other faculty have been concerned with the types of projects that students are engaged in because they may not mirror the curriculum being taught. In particular, projects tend to focus on LEAN initiatives to improve production throughput or facilities design. These projects are heavy in time estimation, flow diagramming and LEAN charting which make up a very small portion of the curriculum. Other projects have involved data analysis related to agronomy, big data or business process engineering which fit a broader range of IE courses. Few projects have been secured around machining/casting/tooling, scheduling, optimization, quality or ergonomics. As a result, faculty in those fields is assisting in identifying appropriate contacts for projects.

Standards conformance is another focus area for the department[4]. From the onset, students are required to research and document which engineering standards are appropriate to their project and then document how they have followed and implemented those standards as the project work is being performed.

Two substantial sources of projects have been the ISU Foundation, who elicits donations from alumni, and also the Center for Industrial Research and Service (CIRAS), which focuses on industry outreach. The projects with CIRAS now represent a substantial portion of the financial impact they report, so that group has recently generated a majority of the new projects during the past few semesters.

Summary of Key Factors

After four years of results, the capstone instructors have developed the following set of critical success factors:

- Successful projects are the primary objective.
- Practicing engineers select, scope and manage the projects from beginning to end. They own the success of the project and may need to jump in and help out if necessary (before, during and after the semester).
- Clients must pay a fee (bigger is better) to ensure a strong commitment to the project's results and student support. Most clients will need to be educated on how to productively assist the students.
- Students must engage the clients personally and often. This has proven very difficult with the students today being dependent on social media.
- Student teams of size 4 work well.
- Student teams should work on unique projects. Having multiple teams work on the same project to achieve unique results has been a disaster due to the competitive nature of the course, as students at top teams are awarded cash and other benefits.
- Students should select their team members and compete for projects based on competency (Internships, courses, grades, job acceptances, etc.)

Conclusion and Next Steps

Overall, the Students, Industry, Department and College consider this approach to be very successful and efforts are underway to model this approach in other engineering departments. Of course challenges exist in convincing faculty to turn over capstone to practicing engineers and/or move to industrial capstone projects.

Currently the IMSE department is experimenting with an expanded model whereby the capstone fee is $10,000 per semester project and this includes additional specified involvement of a Faculty member or Graduate student. This approach has been initially successful with very complex projects involving data analysis or project scopes which span multiple semesters (teams). As of Fall 2017, approximately 15% of the projects were being performed at the $10,000 level and are funding graduate students.

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