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Industry Sponsored Applied Capstone Projects: Experiences in Sourcing Projects, Course Redesign, and Sponsor Engagement

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Abstract

This paper outlines the process, design, implementation and improvements of an industry sponsored applied capstone project for an interdisciplinary undergraduate program. Improvements include moving to industry sourced projects for all teams, course redesign, student and industry engagement, and implementation of a project showcase event. Currently, about 65-70 projects are conducted every academic year. The capstone projects were previously scoped and defined by the faculty. The projects were broad industry challenges, lacked real-world data and had low student engagement since they knew that the projects were theoretical. In the past four years, a team effort was made to source real-world projects from industry.

The two-semester long Capstone Project also underwent a complete syllabus, content, flow, deliverable and timeline update. Enhancements over the years include improvement to project scoping and management, background/literature review, depth of analysis, and overall writing process. A unified syllabus, student deliverable description, rubrics, advisor check-ins, and past project examples help support the student experience and project outcome. Five instructors, all hailing from industry, were assigned to source projects from the industrial and construction sectors. They worked with companies across the country to define and scope projects one to three months ahead of each semester. Given their industry experience, these instructors also acted as the capstone advisors to the student teams. Each project team had five students. The students were required to meet with the company sponsor and the capstone advisor in alternating weeks. A survey process was put in place for advising instructors and students to provide continuous improvement input. External assessments are conducted during the showcase to also provide for continuous improvement as well as used in ABET accreditation.

Background

The XXX program is part of the department of Engineering XXX within the College of Engineering at XXX University, in College Station, Texas. The XXX program prepares students for the technical B2B industries and services. Graduates are placed in technical sales, operations, procurement and supply chain roles with industrial, construction, and wholesale companies. While this niche program has a strong business bend, students are taught to use sound engineering methods to solve problems and make data-driven decisions.

Introduction of Capstone Project

In 2017, the program prepared for ABET accreditation in applied engineering. The Program was reviewed in 2019 and ABET accredited in 2020. With this significant event came the commitment to installing a capstone experience as a way for students to integrate their knowledge and demonstrate their skills. According to ABET, the capstone experience "*develops student competencies in applying both technical and non-technical skills in solving problems*".

The capstone project was set up as a two-semester long project during the final two semesters before graduation. Topics for the first generation of capstone projects were developed by the faculty. Undergraduate students divided up into groups of five and tackled a theoretical project. To provide academic guidance, students would attend a three-credit capstone class that emphasized problem identification and background research in the first semester. Data collection, methodology, and potential solutions would highlight the second semester. The project would culminate with students presenting their work in a poster session.

Faculty-Provided Topics

The first generation of capstone projects started with faculty developed topics for students. The first obstacle was in sheer numbers. A typical cohort would have 30-35 groups of students. This posed a sizable workload for an advisory professor, who would each have to devise eight or so project topics, many of which were not necessarily in the center of that faculty's knowledge domain. For instance, an advisor who specializes in teaching about electrical components may pose, "Provide a de-risked scenario for sourcing electrical materials that are currently imported from Asia." While the components themselves were an area of expertise, manufacturing and sourcing them were not.

The second challenge for the advisor would be their ability to engage in regular student meetings. The advisor position was not yet formalized. The actual role of the advisor, as the project originator, was to meet regularly and provide insights. The contact was predominately student led and resulted in inconsistencies between the capstone teams. The variation led to differences in quality of outcomes between projects.

Limitations

While these early capstones did allow students to apply their competencies from various classes in data-driven decision making, the effort fell short on several fronts in rigor, depth, and the experience of solving real-world problems.

Lack of Data

The projects proposed by the faculty were high-level industry problems or exploratory in nature. These students conducted some literature reviews but lacked access to quantitative and qualitative data to develop specific solutions. The students tried to connect with industry for interviews and surveys, but those efforts didn't yield meaningful data to develop useful solutions or recommendations. Overall, the frustration led to a diminished learning experience.

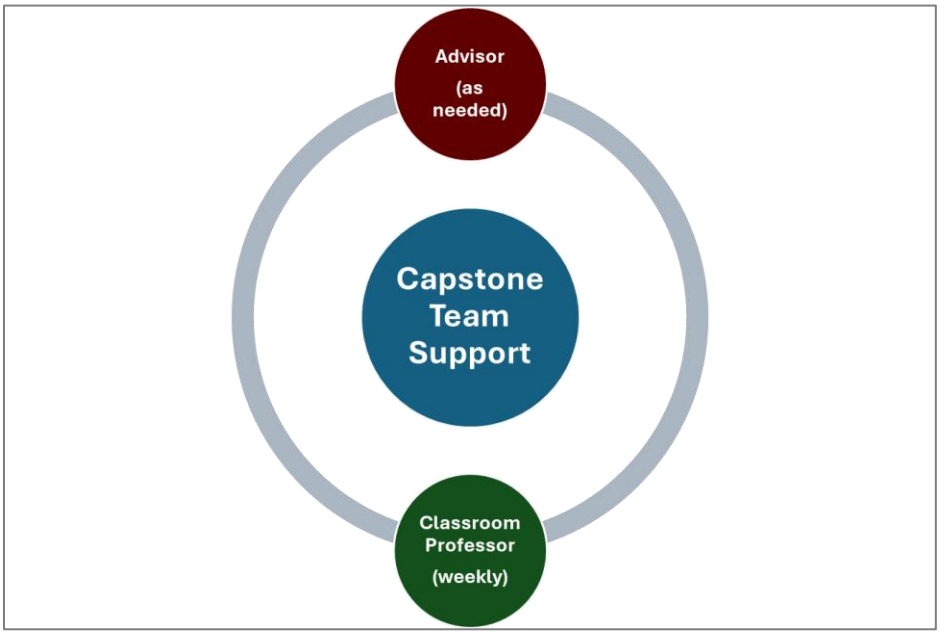
Quality of the Deliverable

Often, the faculty-sponsored capstone ideas resulted in an overview study or survey of industry trends as opposed to a more tangible output. While the students might have collected data and applied a methodology to a problem, the frequent deliverable was a set of recommendations. As a degree program designed to serve the technical goods and services industry, our graduates should be charged with engineering a "better way" within a process. But many project outputs fell short of this. While a set of capstone

recommendations might have captured improved thinking, it came across as "academic" or even "busy work".

In a graduating senior exit survey, conducted in May 2022, a student commented, "*For the capstone, it would be great to have an improvement on the problems assigned. Hopefully, the XX program can find companies to sponsor these and give us [projects].*" Another echoed this sentiment with a "*Desperate need for a better/more industry related capstone*." Finally, one chimed in with an instructive comment, "*Make Capstone more technical.*"

Figure 1. First generation capstone project model.



It was clear that not having real-world cases of applied engineering problems was a demotivating factor for the seniors. There was a need to improve the capstone project experience, especially, the need for industry engagement and a better advising structure.

ABET

Looking at the learning outcomes that ABET requires, we had room for improvement in demonstrating student mastery in the prescribed areas. Much of the improvement could be addressed by ensuring that student teams would formulate more tangible deliverables.

In the case of XX Program, focused on the intersection of engineering and business, this could be in the form of decision-making devices such as spreadsheets, interactive flowcharts, or other algorithms. This could also look like a Power BI display or an AI-aided solution. Any solutions like this would allow the students to better meet these ABET criteria for accreditation:

1. an ability to apply knowledge, techniques, skills and modern tools of mathematics, science, engineering, and technology to solve broadly defined engineering problems appropriate to the discipline.
2. an ability to design systems, components, or processes meeting specified needs for broadly defined engineering problems appropriate to the discipline.
3. an ability to apply written, oral, and graphical communication in broadly defined technical and non-technical environments; and an ability to identify and use appropriate technical literature.
4. an ability to conduct standard tests, measurements, and experiments and to analyze and interpret the results to improve processes; and
5. an ability to function effectively as a member as well as a leader on technical teams.

Charting A Better Way

To improve the capstone project design, focus, and application to industry, a survey was conducted with all the former students in the summer of 2021. The purpose was to learn the types of problems, projects, and challenges our graduates are asked to research, develop, and solve within their first three years of employment. The three KEY questions asked are below. This survey was part of the overall alumni survey. We received **146** responses.

> We are enhancing our capstone project experience. The capstone is the culminating experience for students where they apply their skills to solve real-world problems. Your feedback is very important, and providing us with topics that will provide students with a rich experience is appreciated
> - Please provide us 1 to 3 examples (with brief descriptions) of projects you were tasked to do in the first 3 years of employment.
> - Are there things you wish you had been exposed to at Texas A&M that would have assisted you in the previous question?
> - What software or other tools did you use while working in the project examples you provided?

The responses were analyzed and summarized. While the types of project topics and industries varied, the following three observations were made from the alumni:

- The problems/projects are very specific, narrow and, in most cases, technical in nature.
- Many of the problems/projects involved technology use, either to analyze, automate, or develop dashboards. In general, to effectively use the data, they had to make data-driven decisions and business impact.
- They are looking for a new, better, smarter way to solve problems and hope the next generation of graduates will bring out-of-the-box thinking and creative problem-solving.

Implementation of an Improved Capstone Program

The above survey, findings, and discussions confirmed the need for industry-sponsored projects. The question remained how to source 30-35 high-quality projects per

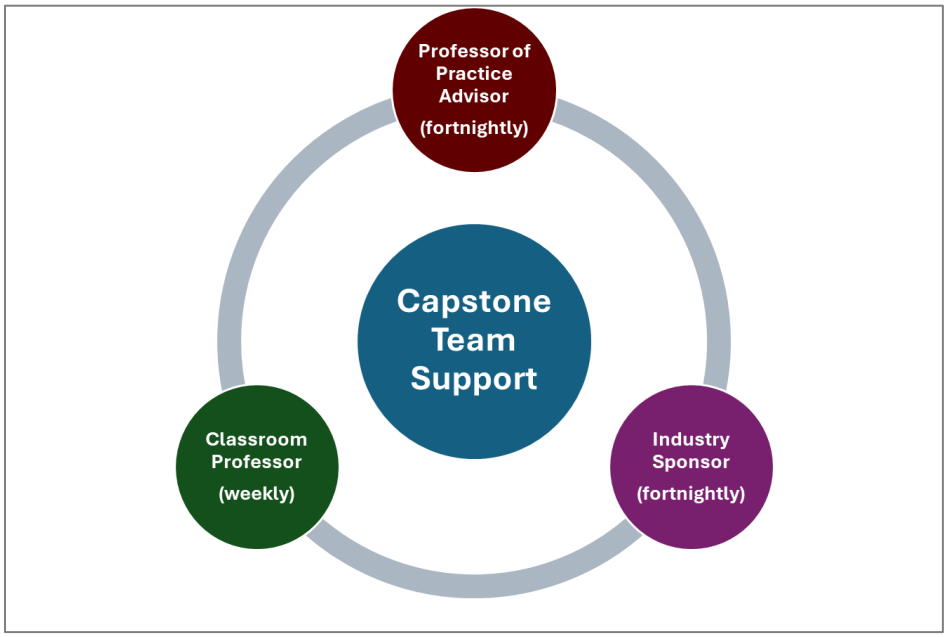
semester. In Fall 2021, It was decided to engage the Professors of Practice (POP) already on faculty to serve as both the project producers as well as the advisors to the capstone student teams. These individuals have business backgrounds and frequently engage industry at events such as job fairs and continuing education sessions for professionals. In so doing, the Professors of Practice were able to advertise the Program's desire for industry sponsored capstone events. Marketing collateral was developed, and solicitations for industry sponsors were made at industry-facing events.

The POPs liaised with industry to develop suitable topics. A basic CRM process was installed to track leads for projects and timing. When a potential fit was identified for the upcoming semester, the POP would work with the company to develop a project topic. Spring 2022 started with half the teams with industry-sponsored projects and by Fall 2022, all projects were industry-sponsored.

Second-Generation of Capstone Projects

Once the topic was launched with the student teams, the POP would meet with them fortnightly. Playing an advisor/mentor role, the POP could discuss classroom materials, team dynamics, industry-related issues, etc. The teams were asked to generate an agenda before the meeting, keep minutes, and issue an after-action summary that captured topics and meeting deliverables. In the intervening weeks, the teams met with the company representative who acted as their industry sponsor. This person would introduce the company, give background to the problem, provide relevant operational/financial data, and "sense check" the team's thought processes and actions.

Figure 2. Second generation capstone project model.



Finally, classroom professors added academic rigor to the capstone experience. These instructors taught the problem-solving process, including defining the problem,

background research, analysis, and engineering design. They also devised assignments that could be ABET assessed for both individual and team performance. Classes would meet three days per week for 50 minutes. The usual format would be a short lecture followed by student-led discussions on either that topic or project progress.

Initial Challenges

Companies posed a broad spectrum of projects. Many were appropriately technical for graduating seniors. There were some challenges, however. Some projects constituted an ambiguous research effort. In others, subjects were beyond the students' grasp. A few were not appropriately challenging for two semesters worth of work.

Another challenge was scope creep. Naturally, a company operates in a dynamic business environment, sometimes with ever-changing business needs. Many companies are highly adaptable and responsive to changing market pressures and would expect the student capstone team to be equally as agile. This could introduce confusion and frustrate the learning experience.

Finally, an obstacle for students was the potential for mixed messaging from the various parties that they engaged with. They were talking with their faculty advisor (POP), their classroom professor, and their company representative. They would often receive differing or even conflicting opinions. While this is somewhat indicative of the "real world", it proved counterproductive for the capstone students.

Continuous Improvements

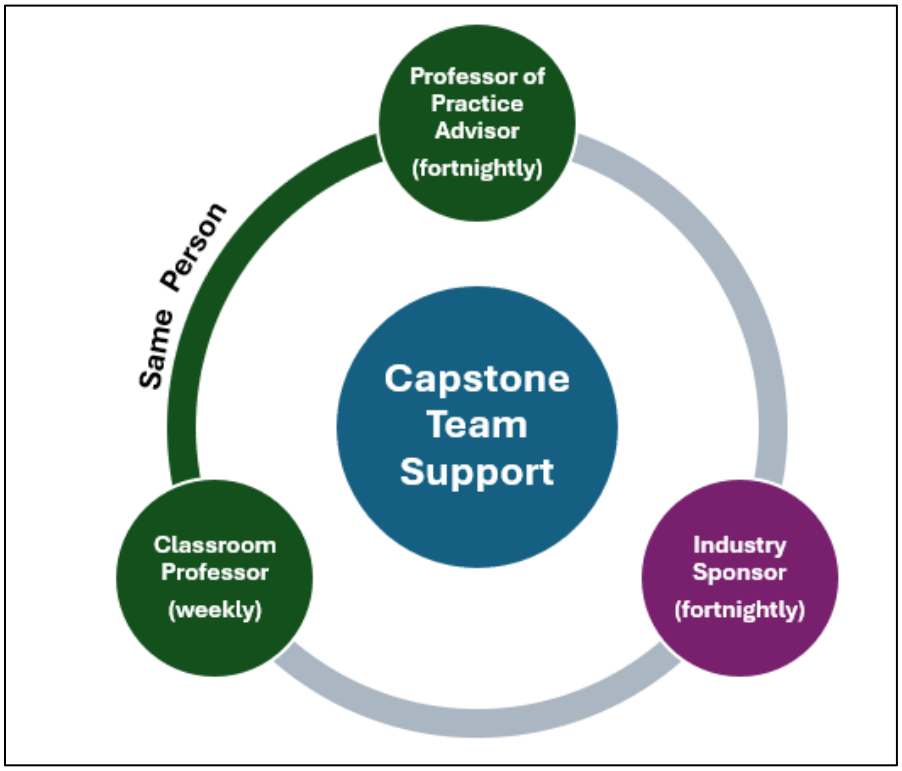
In the case of project appropriateness or scope creep, challenges were largely attributed to a lack of mutual understanding between the industry sponsor and the capstone team. POPs were tasked with bridging this gap by introducing a more formalized project charter format as part of the project identification process. It is comprised of four distinct parts:

1. Background of problem/opportunity that introduces the company and area of interest
2. Destabilizing condition that describes the adverse effects of the problem or the nature of the opportunity
3. Consequences of not solving the problem or acting upon the opportunity
4. The desired outcome(s), without necessarily identifying the solution deliverables

By discussing and agreeing to the points above, the POP and industry partner have a much clearer set of expectations for the team to work from.

To help mitigate the mixed messaging that students were receiving from the various support parties, it was decided to make their classroom professor and advisor one-and-the-same. The course is now exclusively taught by the Professors of Practice, who also meet separately with the teams to act as their advisor.

Figure 3. Third generation capstone project model.



Benefits to stakeholders

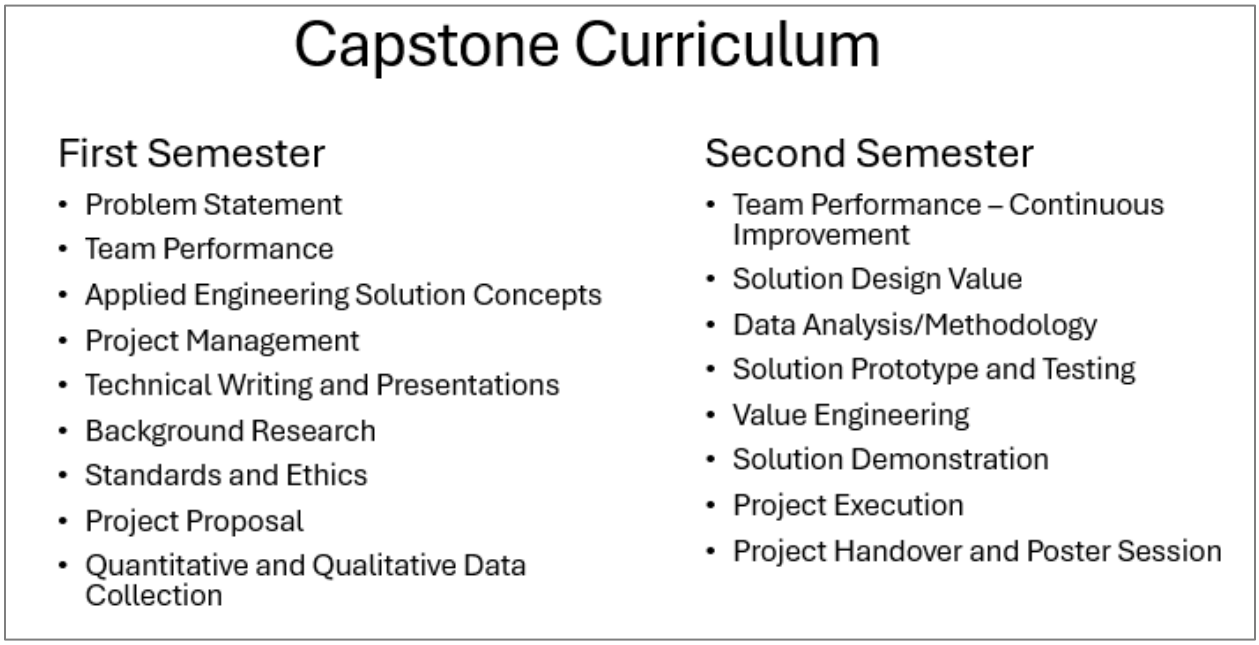
Students
Students benefit from the company-sponsored experience through relevant, "real-world" projects. The prospect that their work will be used as a profit-generating endeavor is a motivator for them. Through meetings with their sponsor companies, they are exposed to the pace, jargon, expectations, and challenges that they may encounter post-graduation.

Sponsor Company
Companies benefit from the practicality of the students' deliveries. Students conduct a formal "handover" of their completed project so that companies can fully leverage the work. Companies also benefit from name recognition within the XXX program. Students highlight their interactions with the companies during class as well as the final poster session. A few companies have even hired students from their capstone teams.

Program
The program enjoys closer working relationships with industry while reinforcing learning concepts. Topics are circulated amongst the research faculty for furthering industry discussions. The more robust capstone process strengthens demonstration of ABET conformance.

Final Capstone Curriculum and Explanation of Subjects
While the process is continuously improved, the latest iteration balances applied engineering and business concepts while providing an accreditation-compliant and practical student experience.

Figure 4. Current capstone curriculum flow and deliverables.



First Semester

- **Problem Statement** – Definition of problem in four parts: background, destabilizing context, consequence(s), and solution(s).
- **Team Performance** – Expectations are established and codified in a group performance contract. A robust peer review process has been introduced to help maintain individual student accountability.
- **Applied Engineering Solution Concepts** – Reviews systematic research, design-centric thinking, and systems engineering.
- **Project Management** – Basic concepts such as GANTT charts, work breakdown structures, and communication protocols with stakeholders.
- **Technical Writing and Presentations** – Review of skills that result in referenced, clear, and concise communication.
- **Background Research** – Student identify areas of research for their groups that further their mastery of the project topic. This could be general domain knowledge or specific areas of the problem or potential solution.
    - Note: having students research each identified area as opposed to a student each taking a specific area results with more productive collaboration within the team.
- **Standards and Ethics** – Areas relevant to each project are identified and discussed both within and between the teams.

- **Project Proposal** – This is a document that serves as the agreement between the team and the sponsor company. It specifies the formal problem statement, background, goals, information needed, deliverables, and target value.
- **Data Collection** – This process is started before the end of the semester to take advantage of the break. Students might request quantitative data to give the company ample lead time or perhaps employ a survey process that can run between semesters.

Second Semester

- **Team Performance** – Time is taken to reflect on the first semester's performance, both as a team and an individual. Semester One's assignment grades, peer review, advisor feedback, and overall grade can all be considered. Students will update their Group Contract accordingly to promote continuous improvement.
- **Solution Design Value** – Students take the role of a consultant who will pitch their project. They will devise and present a sales brochure that promotes project clarity, risk, and financial impact.
- **Data Analysis/Methodology** – The method of analyzing the data collected is demonstrated. The application of statistics, formulae, and artificial intelligence are all encouraged.
- **Solution Prototype** – Beta testing to ensure robustness and conformance to the Project Proposal.
- **Value Engineering** – Groups demonstrate deliverables looking for ways to minimize cost, enhance impact, and decrease risk
- **Solution Demonstration** – Conducted in front of the class
- **Project Execution and Handover** – Materials are handed over to the sponsor company with emphasis on operation, scalability, and demonstration of value.
- **Poster Session** – Student present a summary of their project, to include problem statement, discoveries, alternatives, roadblocks, solutions, and value. This is presented to faculty and industry.

Student Feedback

Feedback from 2024 graduating senior surveys has indicated that improvements in adding the Professors of Practice and industry sponsorship are being felt.

> "*I think (the POPs) give a great understanding of an overall basis of what the industry entails. I really enjoyed the Capstone project and having the industry experience through the class*."
>
> "*The capstone projects are great, the presentation focus is great, and the professors of practice are a good addition because of their experience and ability to share (their) experience*."
>
> "*The Capstone experience helps set the ID program apart by working directly with a company sponsor*."
>
> "*Great professors of practice are a great addition (to capstone).*"

Figure 5. Capstone Project showcase.

Future design and execution improvements

In the spirit of continuous improvement, two areas deserve attention.

Team formation: Presently, teams are formed randomly, the premise being, "you don't usually choose your teams at work." There is little deference given to the complementary skills and personalities of the students within the team. Work needs to be done to identify a quick and fair way to promote diversity of thought and skill balancing amongst the teams.

Project Sponsor Companies: The second area of improvement is with the companies themselves. Identifying 30-35 projects per semester is a formidable task. While most sponsor companies approach the capstone as a serious opportunity, for some, business shifts or people changes can shake committed projects loose during the two-semester span. Work must be done to provide a more sustained effort across all the capstone industry sponsors.

Implications

The key learnings from this capstone project design, development, implementation and execution over three years helped the program to (1) Understand and implement narrowing the project focus and scope management, (2) Work on industry-sponsored

projects, help prepare students become industry-ready professionals. As most entry-level professionals are now working on projects and within a few years of graduation will lead projects and (3) Assigning the Professors of Practice to source, manage and advise the project teams helped streamline the expectations, customer management and project quality control.

Conclusions

Projects have now become clearer, eliminating ambiguity and are centered on the developmental process for high-utility and valuable deliverables. The four-step process of identifying the project helps students focus, highlighting the need for them to develop a tangible result and minimizing the risk of scope creep driven by the company's dynamic business environment. Streamlining the model of engagement for the students helps minimize confusion and reduce frustration. The combination of the professor/advisor, in conjunction with regular meetings with the industry sponsor provides a consistent cadence of engagement with students. This drives accountability and promotes continuous advancement of their project.

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