

## **Pitfalls to Avoid in Industry Capstone Project**

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### **Abstract**

The capstone course in the B.S. in Industrial Engineering Technology (IET) program (accredited by ETAC of ABET) gives each student the opportunity to demonstrate the ability to accomplish the integration of systems using appropriate analytical, computational, and application practices and procedures. Students are expected to use technical and non-technical skills to solve a problem in industry. The Six Sigma DMAIC model is used to manage the project. Some students also use the project for entry in the University-wide annual research symposium and/or Six Sigma Green Belt or Black Belt certification.

The project is used for assessment of several program learning outcomes. In fact, this paper/presentation will cover continuous improvement opportunities that were identified through the assessment of the project work. Some of the problems that were identified and addressed include inadequate and untimely project selection by companies, students wasting time getting started, weak team leadership, and ambiguous root causes.

### **1. Introduction and Overview**

“The ET department's emphasis on solving real world problems has prepared me to avoid the pitfalls that many of my peers encounter and start achieving results early in my career.” That is a direct quote from an alumni survey I received in the summer of 2017. Year after year, alumni surveys validate a strength of the ETAC of ABET accredited B.S. in Industrial Engineering Technology program at Missouri Southern State University: students gain hands-on experience during their studies through industry projects. Whereas students have multiple opportunities to do projects in industry while pursuing the degree, the capstone project provides an opportunity for a culminating experience where students have the opportunity to identify, analyze, and solve broadly-defined technical problems using appropriate methodologies and tools.

Continuous assessment of the capstone project has led to many changes in the facilitation of the course to help continuously improve the project outcomes. The paper will address just four issues that were identified as problems.

### **2. Course Background**

Students enroll in the 1 credit hour capstone design course their senior year. The capstone design experience allows students to apply their technical and non-technical knowledge to actual industrial problems. The Six Sigma DMAIC model is used to manage the project. The project may draw on knowledge gained from any course in the curriculum. Students will either do

individual projects or team projects, depending on whether the project is the capstone project for the B.S. in IET program or will be used as part of six sigma green belt or black belt certification. Individual projects may also be used for entry into the Missouri Southern State University undergraduate research symposium.

The design activity includes identification of problem, objective, financial benefits, activity plan, customer analysis, data collection and analysis, generation and validation of root cause, generation and assessment of solutions, and recommendations for and where possible, development of systems improvement. Students will have to balance corporate expectations with academic requirements.

Project examples from the spring 2017 capstone design course are outlined in Table 1.

Table 1. Three Project Examples from the Spring 2017 Capstone Course.

Project Title	Problem Statement	Objective	Projected annual savings (\$), certified by company
Reducing Defects at IFS Assembly	From October 2016 through January 2017, the IFS assembly line detected defects on finished units that accounted for over \$22,000 in scrap, rework, and replacement costs. The first pass yield was 87%.	Reduce the number of defects per unit by 50% and improve the first pass yield by 50%.	\$33,000
Week 1 Efficiency Improvement	The Week 1 CNC Router has a monthly efficiency rating between 40% and 60%.	Increase the monthly efficiency to at least 70%.	\$24,923.08
Labor Hour Reduction	A certain cable assembly is not meeting labor hour bid. In 2016, the average labor was 83% higher than what was bid which led to negative margins on the program.	Reduce the direct labor hours to achieve bid. Implement improvements across other assemblies.	\$25,000

### 3. Six Sigma Certification and Research Symposium Options

Every B.S. in IET student participates in a capstone project. Whether the project is an individual project or team project depends on whether students pursue a six sigma belt certification. If students meet certain grade requirements, they qualify for belt certification and may choose an individual project that doubles as capstone and certification project. All others do team projects with two or three people on a team. All projects are managed by the student(s) and all projects have team members from the company sponsoring the project.

Students doing individual projects qualify for entry in the annual Missouri Southern Undergraduate Research Symposium. In the spring of 2016, we had students take 1<sup>st</sup> and 2<sup>nd</sup> place and in the spring of 2017, we had one student take 1<sup>st</sup> place in their respective categories.

#### 4. Project Deliverables

The project deliverables and associated deadlines are shown in Table 2.

Table 2. Project Deliverables and Deadlines

Deliverable	Due Date
<b>Preliminary Report</b> (Company, project sponsor/champion, problem statement, objective, business case, Gantt chart & activity chart, charter, agenda for two meetings at company, team members from company, anticipated meeting days and times for meeting with the company, team leader for group projects, meeting days and times for group projects).	Week 3
<b>Define Milestones</b> (Graded 1 <sup>st</sup> preliminary report, updated charter, as-is process map, customer analysis including CTQs, stakeholder analysis chart, stakeholder assessment table, updated activity report and Gantt chart, affinity diagram about project scope that was developed by the team, plus/deltas from last meeting with the company, ground rules developed by the team, meeting log with dates, times, locations, and attendance since project start).	Week 6
<b>Measure Milestones</b> (measures/metrics related to the project, operational definitions, data collection plan, data collection forms, meeting log with dates, times, locations, and attendance since project start).	Week 8
<b>Literature Review</b>	Week 9
<b>Financial Benefits/Updated Gantt/Activity Chart</b>	Week 11
<b>Poster</b>	Week 14
<b>Presentation</b>	Week 14 or 15
<b>Report</b>	Week 14 or 15

#### 5. Assessment of Capstone Project

The capstone project is used to assess the following learning outcomes as part of the B.S. in IET program assessment plan.

- Ability to apply knowledge, techniques, and skills of engineering economics.
- An ability to design systems, components, or processes while accomplishing the integration of systems using appropriate analytical, computational, and application practices and procedures.
- An ability to identify, analyze, and solve broadly-defined engineering technology problems.
- An ability to apply written, oral, and graphical communication in both technical and non-technical environments; and an ability to identify and use appropriate technical literature.
- Commitment to (a) quality, (b) timeliness, and (c) continuous improvement.

## 6. Problems and Lessons Learned

Some of the problems that were identified through the assessment of the capstone course include inadequate and untimely project selection by sponsoring companies, students wasting time getting started, weak team leadership, and ambiguous root causes.

### 6.1 Inadequate and Untimely Project Selection by Sponsoring Company

Many times, a company will commit to sponsoring a capstone project but then drag their feet on getting a project and a project sponsor identified and/or submit inadequate project suggestions. This can severely delay project start or drag the Define stage of the DMAIC model out so it takes an unreasonable amount of time to define the project opportunity. This in turn will give students a delayed project start and often decreases their motivation and the team's motivation towards the project.

Improvement efforts to counter that problem include giving companies a “heads up” that the IET program is seeking capstone projects a few months prior to semester start. It is announced during the industry advisory board meeting and an e-mail is sent out about a month prior to semester start to participating companies. The communication includes the criteria for a “good project.” Then two weeks prior to semester start, the company must submit a problem statement and objective. This often involves multiple forms of communication and some coaching on what types of projects qualify as capstone projects. Good projects have the following characteristics: There must be a gap between current and desired performance of a process, the root cause must be unknown, and the solution must not be obvious or be identified. The problem statement and objectives may be modified after the students meet in their teams, however, having the problem statement and objectives at the start of semester allows for a timely project start. It also holds the company accountable for the scope of the project. The problem statement, objective, and company sponsor are officially documented in the project commitment agreement that the company sponsor signs.

### 6.2 Students Wasting Time Getting Started

At the beginning of the semester, many students think the semester lasts forever and there is plenty of time to do things...no need to rush into anything. They perceive the 15-week time frame for a project as something to start worrying about half-way through the semester. With that attitude comes a reluctance to contact the company to get the logistics for project meetings in place, and truly understand the project problem and objective. Sometimes, we are in week 6 and students are still unclear about the problem they are supposed to solve and haven't had their third meeting with the industry team members. This is more likely to happen if the company mentor has never sponsored a project or is unfamiliar with the DMAIC model and if the student has not been familiar with the company through other projects or internships.

Continuous improvement efforts that helped with procrastination included having homework assignments with deadlines early on with deliverables such as an affinity diagram developed by the team to scope the project and clarify the problem statement, Gantt chart, agendas for the first

two meetings, meeting minutes for the first two meetings, ground rules developed by the team, and Plus/deltas developed by the team.

There are always “early birds” in the student body who are ahead of their peers in terms of deliverables. It helps having those students present their deliverables and share their experiences in front of the class. Students seem a lot more interested in present classmates’ experiences than anything I can show them from former students. Sharing peer experiences also drives home the message that the DMAIC model works, don’t miss a step and apply all the tools that are appropriate.

### 6.3 Weak Team Leadership

It isn’t easy for students to establish themselves as project leaders in a company for the fact that they are still students. Often company team members are engineers, supervisors, and/or operational employees who don’t see students as professionals by default. This is especially true for students who don’t have a prior relationship with the company and/or who haven’t sought out leadership roles in the past and are inexperienced in the leadership role. This problem gets intensified if the sponsoring company isn’t familiar with the DMAIC model for problem solving and doesn’t understand the emphasis on taking time to understand the current situation and identifying the root cause prior to developing solutions. If a student doesn’t establish him/herself as a competent project leader, they may have to deal with maladaptive behavior by company team members such as no-shows, inadequate sharing of information, non-performance of action items, and refusing to follow the problem solving methodology.

In order to get students ready to be good project leaders, they are taught Tuckman’s stages of team development and their responsibility as team leaders to get the team to the performing stage.<sup>1</sup> They are also taught about the five dysfunctions of a team and given specific exercises and suggestions to overcome those dysfunctions.<sup>2</sup> Most importantly, students are taught facilitative preventions such as use of agendas, parking lots, plus/deltas, ground rules to ensure the meetings are productive.<sup>3</sup>

As part of continuous improvement efforts, students are required to show proof of implementing those facilitative preventions in the preliminary report to force students into using facilitative preventions. Unfortunately, requiring proof of application of a tool doesn’t guarantee students follow through. Students have admitted to “making up content” like ground rules and plus/deltas (a method used to assess team meetings) just to satisfy a homework assignment. Telltale signs of fictional homework deliverables are students complaining that meetings don’t go as planned, meetings are unproductive, and team members are not participating fully in and outside of meetings. When students are pressed on their experiences with facilitative preventions, they quickly admit that they have not implemented them because they didn’t feel it necessary. After all, everyone is a professional, right? One method to increase true buy-in into the facilitative prevention tools is to have “early bird” students share their deliverables and experiences as they implemented facilitative preventions. Getting timely encouragement to use the tools and hearing actual feedback from peers increases the number of students using the tools and with it the chances that the project team meetings are productive.

## 6.4 Ambiguity About Root Cause

One of the project deliverables is identification of root cause. This includes the process and/or data analysis that leads to potential root causes and the verification of the root cause. Some students only show a weak connection between data and/or process analysis and root cause hypothesis and validation. In such cases, the root cause seems to appear out of “nowhere.” There is barely any evidence (data or process analysis) to validate the root cause.

The improvement efforts to resolve this problem included instructor feedback on preliminary drafts and encouraging students to take greater efforts to collect data for data analysis and process analysis. Also, more weight was placed on detailed data collection plans and data collection sheets as part of the final report. Initially, that backfired and assessment results showed that students were performing worse regarding root cause validation. To make matters worse, students also scored worse on the continuous improvement commitment because they didn't follow up adequately on my multiple warnings about insufficient data collection in the various drafts and homework assignments. What finally made a difference and moved assessment results in the right direction was spending more time in lecture about keeping stratification in mind when developing data collection plans and practicing operational definitions and data collection plans in teams on the white boards based on scenarios. Every student also was required to share their project data collection plan and sheet as part of a homework assignment in front of class. Those data collection plans and sheets were then critiqued by the class. This allowed students to see several examples of other projects, identify weaknesses, and receive feedback on their own.

## Conclusions

This paper gave an overview of an Engineering Technology capstone course and detailed some of the problems the author experienced throughout her years of teaching the course. While the author recognizes that teaching a capstone course will always require continuous improvement activities, some remedies that worked for her course were identified.

## Bibliographic Information

<sup>1</sup>Tuckman, B. W. (1965). Developmental sequence in small groups. *Psychological Bulletin*, 64(6), 384-399.

<sup>2</sup>Lencioni, P. (2002). *The five dysfunctions of a team: A leadership fable*. San Francisco: Jossey-Bass.

<sup>3</sup> Eckes, G. (2003). *Six sigma team dynamics: The elusive key to project success*. New York: John Wiley.

## Biographical Information

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