Using Six Sigma as a Problem-Solving Methodology for Senior Design Projects

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Abstract

Senior design projects require students to demonstrate the integrated application of their industrial engineering skills, knowledge, and tools learned throughout their curriculum. At University of San Diego (USD), projects involve identifying and solving a real life problem in the field of industrial engineering. For many students, however, the unstructured nature of these projects present new challenges. "What problem solving methodology can I use to solve an unstructured problem?"

Six Sigma is a proven process improvement methodology used in industry for solving problems. The Six Sigma philosophy and methodology started at Motorola in the 1980's has gained popularity in industry is based on the DMAIC model which contains five steps: Define, Measure, Improve, and Control. The DMAIC method provides the framework to improve the capabilities of an existing process by reducing variation, defects, or even costs. The DMAIC is a structured problem solving methodology that incorporates a majority of the process improvement tools introduced throughout an Industrial Engineering student's career at the university. The DMAIC methodology can provide students with the framework and structure necessary to successfully complete an open ended project within the specified timeframe. The paper presents how the DMAIC methodology has been incorporated into the senior design project at USD.

Background

The Industrial & Systems Engineering (ISyE) department at University of San Diego includes broad coursework across the spectrum of ISyE disciplines including engineering economics, statistics, manufacturing, human factors and operations research. The number of students in each course varies, but usually ranges from 10 to 25 students. The Senior Capstone Course is one semester course that culminates the students' experience within the department. ISyE students are also required to complete a comprehensive set of general education requirements leading to a nine semester, 149 unit dual B.S./B.A. degree in Industrial & Systems Engineering.

Introduction

Senior ISyE students are required to take a one semester senior capstone design course. As with many capstone courses, the capstone experience is meant to be an integrative experience in which students apply their Industrial Engineering knowledge and skills acquired over the previous four years. The senior design capstone course description is:

> *ISyE 490 Industrial Engineering Design*
> Capstone senior design project. Application of principles of Industrial Engineering from throughout the curriculum to a design project. Written and oral reports, design reviews, final project report and presentation. Three hours lecture and one laboratory weekly.

This course provides the capstone Industrial and Systems Engineering experience at USD. In the course, students are required to complete all aspects of a project from preparing the proposal to presenting recommendations. Students are expected to draw on their principles learned in many of their courses. At USD, we solicit projects from local companies in order to provide students a "real-life" project. The open-ended nature of real-life projects requires students to determine which skills to apply as well as how to apply them. This can be a great learning experience for students, but there are many challenges presented to students during the senior design project. The main challenges identified include; project and time management, lack of technical depth, and lack of structure.

Engineering management is one of the biggest challenges students face during their senior design projects. American Society of Engineering management (ASEM) defines engineering management as "the art and science of planning, organizing, allocating resources, and directing and controlling activities which have a technological component" [1]. Students need to be introduced to engineering management in order to achieve any type of success on their projects. Ravikumar provides a brief explanation of the necessary management content that should be included in a senior design course [2].

Another challenge encountered by students is obtaining the required technical content expected by the faculty. Students have trouble maintaining the required pace in order to have sufficient depth by the end of the semester. The students are used to cramming for the exam the night before, but this is not acceptable for a senior design project. In the past, students are spending an increasing amount of time as the semester progresses with the last two weeks doubling or tripling their time. This phenomenon is also encountered other capstone design courses at Trinity University[3] and Rowan University[4].

Lack of structure is an inherent trait of a senior design project. Most students have not been introduced to a project that spans more that one to two weeks. Students expect the professor to provide weekly guidance on the necessary tasks and project direction. This concept varies greatly within faculty members. The million dollar question is; "How much should I hold the students' hand during the semester?"

Six Sigma Methodology

Six Sigma is a systematic, data-driven quality improvement methodology that has proven quite effective in recent years. Specifically, it is an approach by which a cohesive collection of quality improvement tools are utilized to reduce process variation. Developed in 1986 by Motorola, Six Sigma allowed the organization to reduce manufacturing costs by $1.4 billion from 1987-1994.

More recently, their commitment to Six Sigma has allowed them to save a reported $2.5 billion annually. The continuous improvement methodology is based on the Plan-Do-Check-Act methodology developed by W. Edward Deming. The Six Sigma methodology is defined as follows:

> A methodology for pursuing continuous improvement in customer satisfaction and profit that goes beyond defect reduction and emphasizes business process improvement in general[5].
>
> Six Sigma offers a structured method to improve performance. Its methodology is based on established statistical process control techniques, data analysis methods and systematic training of all personnel involved in the activity or process targeted by the program. Six Sigma is a well-structured, data-driven methodology for eliminating defects, waste or quality problems in manufacturing, service delivery, management and other business activities[5].

The key word in both definitions is "methodology". Six provides a structured problem-solving framework that can be applied to any business or engineering process. Traditionally, Six Sigma has been applied in the manufacturing process arena but is rapidly spreading to the service sector. The financial, health care, educational, and government sectors are embracing Six Sigma as methodology to improve their business processes.

The Six Sigma Methodology

The Six Sigma methodology involves "define -measure-analyze-improve-control" (DMAIC) phases. The strategy is to use the five phases to provide the framework to improve a process. The five phases are depicted in Figure 1.

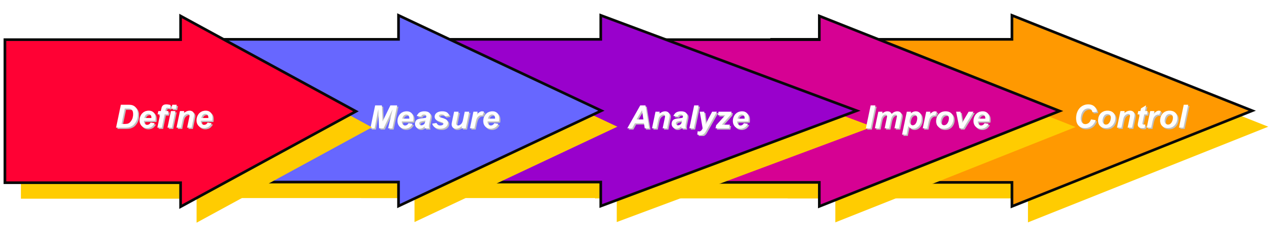


Figure 1: Six Sigma Methodology Phases

Phase 1 – Define
The define phase involves defining the scope and goals of the improvement project in terms of customer requirements and the process that delivers these requirements represented in a project charter.

Phase 2 – Measure
This phase involves measuring the current process performance – input, output and process - and calculating the sigma metric for both short and longer-term process capability. One must also ensure that the measuring device and procedure are reproducible and repeatable so that there is confidence in the data collected.

Phase 3 – Analyze
The analyze phase involves identifying the gap between the current and desired performance, prioritizing problems and identifying root causes of problems. Benchmarking the process outputs, products or services, against recognized benchmark standards of performance may also be carried out. Depending upon the performance gap found, a decision will be made as to whether the existing process can be improved or whether it should be redesigned.

Phase 4 – Improve
The improve phase involves generating the improvement solutions to fix the problems and prevent them from recurring so that the required financial and other performance goals are met. Creativity will be required to find new ways to do things to the quality, cost and time standards required by the performance improvement goals.

Phase 5 – Control
The Control phase involves implementing the improved process in a way that "holds the gains". Standard Operating Procedures (SOP) will be documented in systems such as ISO9000 and standard measurement procedures will be established using techniques such as statistical process control (SPC). The cycle is repeated, if further performance shortfalls are identified.

The DMAIC phases are presented here briefly, but can be seen in detail in Breyfogle[5].

Application of Six-Sigma in a Senior Design Project

As reported earlier, the main challenges identified include; project and time management, lack of technical depth, and lack of structure. Six Sigma methodology addresses the lack of structure challenge directly and the other challenges indirectly.

Six Sigma provides a structured framework for students to apply during the senior design project. Students can apply the DMAIC phases directly to their project. As Industrial Engineers, we are in the business of improving processes using the best tool for the problem. The DMAIC provides a recommended set of tools to use in each phase of the Six Sigma methodology. For example, when students are defining their project (Define Phase), there are tools listed that students can choose from. Figure 2 shows a comprehensive list of tools for each phase of the DMAIC.

The DMAIC phases can be used as a project organizational and planning tool. Even though the students have no project experience, the Six Sigma methodology can provide insight on what will be expected in the phases to come. Students can review past Six Sigma projects to see how and when tools are applied in each phase of the project.

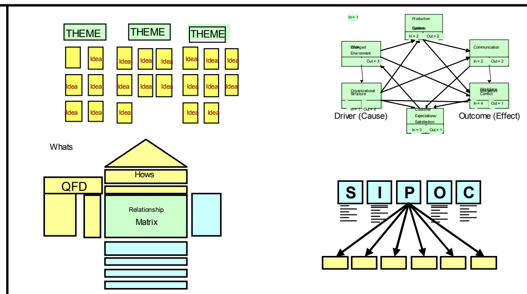
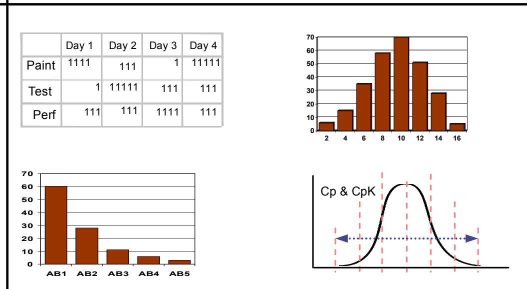
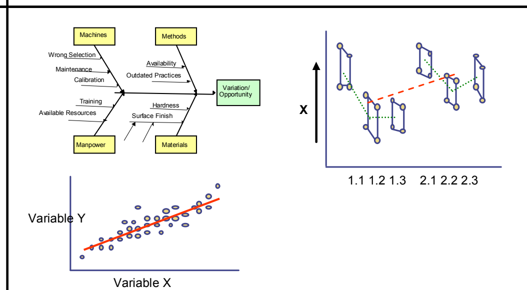
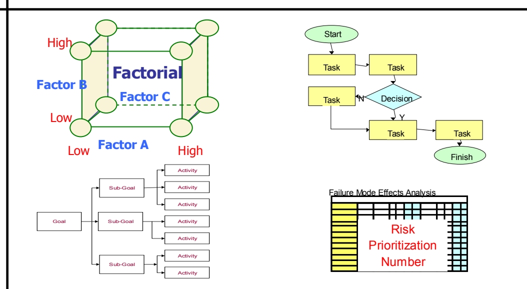
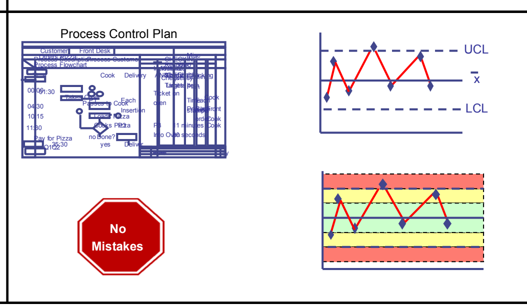
	Objective	Tools and Techniques	
Define	Identify Business Drivers Select Customer Critical Processes Define Projects Develop Implementation Plan	Affinity Diagram/ Interrelation Diagram Quality Function Deployment SIPOC Process Map Project Charter	
Measure	Develop Key Process Measures Collect and Analyze Data Identify the Vital Few that have the Greatest Impact Estimate Process Capability Measurement Systems Analysis	Data Collection Plan Check/Data Sheet Pareto Chart Gage R&R Histogram Process Capability	
Analyze	Understand Cause and Effects Create Multi-vari Analysis Determine Variance Components Assess Correlation	Cause and Effect Diagram Multi-vari Charts Scatter Diagram	
Improve	Develop and Evaluate Solutions Implement Variation Reduction Standardize Process Assess Risk Factors	Design of Experiments Deployment Flowchart Tree Diagram FMEA	
Control	Implement Process Control Implement Control Charts for Key Variables Mistake Proof Processes Evaluate Results	Process Control Plan Control/Pre-Control Chart Poka-Yoke Pareto Chart (on-going) Process Capability (on-going)	

Figure 2: DMAIC phases and tools

The DMAIC phases can be used on a Gantt chart to provide the necessary framework for students. The phases and tools can be used as the high level project events necessary for a successful completion. The DMAIC phases do not provide all of the details, but do provide insight and assistance to the initial timeline. This will help address the challenge of time and project management.

The student project report and presentation require most of the students' effort and usually carry the most points toward their grade. In the past, students are lost when organizing their final project and presentation. The students have an enormous amount of data, analysis, and conclusions that need to reported and presented. The DMAIC methodology lends itself perfectly to reporting and presenting results. The students need to:

1. Define the problem (Define Phase)
2. Measure and collect data (Measure Phase)
3. Analyze and report current process (Analyze Phase)
4. Propose new improved process (Improve Phase)
5. Make recommendations to sustain improvement (Control Phase)

The Six Sigma methodology provides an excellent structured framework for process improvement and is a great fit for senior design capstone projects.

Assessment

After completing the senior capstone design course in Fall 2004, there were several lessons learned. Even though the course is a one semester course, the assessment is applicable to all senior design courses. The main concerns of the student and faculty are presented below.

Students were not comfortable with the Six Sigma Methodology
Students were introduced to Six Sigma methodology in the Systems Engineering and Statistical Process Control (SPC) courses in their third year. They also received a three hour lecture on Six Sigma during the second week of the senior design course. As their instructor, I felt this was a sufficient introduction to the methodology, but after completing a senior project, I have changed my hypothesis. Students needed to be assisted more as the semester progresses, not just in the beginning. One recommendation is to have students present at the end of each phase of the methodology. I require my consulting projects to do so, but it was an oversight on my part. I felt weekly student contact time would suffice, but the students need milestones to keep on track.

We could not get enough data.
Students complained about acquiring data and that it was difficult to obtain. It is a real-life problem that many Six Sigma projects encounter. Students also became caught up in the political problems at the workplace and became infatuated with departmental "finger pointing". I repeatedly reminded them, "Let the data do the talking". It was not enough. More effort by the professor to ensure data collection is a must.

Tools not comprehensive for the diversity of ISyE projects
The Six Sigma methodology is not a totally inclusive set of tools. This is understandable. ISyE students are introduced to many more tools than the ones presented in the DMAIC. Students should be encouraged to use all applicable tools that will improve the current process. As seen in current trends, lean improvement tools are being added to the DMAIC methodology.

Conclusion

The Six Sigma methodology can be used to provide an excellent structure framework for senior design capstone projects. It helps alleviate challenges such as project and time management, lack of technical depth, and lack of structure. The methodology can assist in developing project GANTT charts, project reports, and presentations. There is a learning curve associated with utilizing the tool so initial guidance and assistance may be necessary until students become more comfortable with the methodology. The Six Sigma methodology is not a silver bullet.

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