Improving the Community Through Six Sigma in Engineering Education

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Abstract – Six Sigma is a quality management philosophy, problem solving approach, and statistical measure that helps organizations improve processes, reduce variation, and eliminate waste. The Industrial Engineering and Management Systems Department at the University of Central Florida has incorporated service experiential learning opportunities into the curriculum within a Total Quality Improvement course that helps to tie the community to engineering education. This course teaches the Six Sigma body of knowledge and provides hands-on Six Sigma project experience in community organizations. The course and this paper addresses several components of the Engineering 2020 VISION of the Future, focusing on enabling students to improve their critical thinking abilities, teamwork, and communication skills, as well as enhance their understanding of how engineering tools can impact community organizations.

Keywords: Six Sigma, Engineering Education, Total Quality Improvement, Quality Management

INTRODUCTION

The Industrial Engineering and Management Systems (IEMS) department in the College of Engineering and Computer Science at the University of Central Florida has incorporated community-based service experiential learning into their curriculum. The Total Quality Improvement course, ESI 5227, is a graduate level course that focuses on the development of tools for the management and improvement of quality in different organizations. [Furterer, 1] Essential concepts, practices, and methods of modern quality improvement tools are discussed, along with the Six Sigma DMAIC (Define, Measure, Analyze, Improve, and Control) problem solving approach, and critical success factors to team building and teamwork. Six Sigma team projects are performed that apply the class lecture material to "real world" organizations. There is a requirement that each organization be a community-based organization, or have some component of providing a benefit to a community organization. The course incorporates many components of the Engineering 2020 VISION of the Future, focusing on enabling students to improve their critical thinking abilities, teamwork, and communication skills, as well as enhance their understanding of how engineering tools can impact community organizations. A summary of the Engineering 2020 VISION of the Future [National Academy of Engineering, 2] will first be presented describing the approach of the study, many impacts to engineering education and the attributes that the engineers of the future should possess. A description of the Total Quality Improvement graduate course in the Industrial Engineering and Management Systems department at the University of Central Florida, the instructional strategies applied, and a description of the course components will be discussed. A mapping of the course components and how they help our engineers prepare for the

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2020 VISION of the future will be presented. Lastly, a discussion of how the students' evaluation of the instructor provides evidence that the course objectives were met is presented.

ATTRIBUTES OF THE ENGINEER OF THE FUTURE

The purpose of the National Academy of Engineering study is to prepare for the future of engineering by asking the question, "What will or should engineering be like in the year 2020?" The study also asked "How can engineers best be educated to be leaders, able to balance the gains afforded by new technologies with the vulnerabilities created by their byproducts without compromising the well-being of society and humanity?" [National Academy of Engineering, 2] The study used different strategies to consider scenarios to define the skills that engineers would need and allow them to eventually design curricula that would prepare engineers for many possible scenarios of the future. The four strategies they considered were: 1) the next scientific revolution, 2) the biotechnology revolution, 3) the natural world interrupts the technology cycle, and 4) global conflict or globalization. The study identified many impacts to engineering education. The authors of the study believe that higher educational institutions must teach engineers how to learn, so that they can continue their education after they graduate from a college or university as a life-long learning career strategy. Engineers need to have a systems perspective, and be able to work in multi-disciplinary teams. The engineers in the future need to be able to communicate with technology, be flexible and receptive to change. They must treat others with mutual respect. Engineers must understand the complexities associated with a global market and incorporate the social context of the technical, legal, market and political perspectives. Engineers must know how to deal with the concept of "customerization" which is a buyer-centric business strategy that combines mass customization with customized marketing. Engineering will need to develop a stronger sense of how technology and the public interest interact with community-based organizations, and an understanding of public policy. Engineers need to be broadly educated and view themselves as global citizens. They need to be leaders in business and public service who are ethically grounded. Engineering curricula need to incorporate case histories. [National Academy of Engineering, 2]

The study identified several attributes needed by the engineering graduates in the year 2020, including strong analytical skills where they can incorporate the impact of social systems and their constraints, as well as economic, legal and political constraints. Engineers need practical ingenuity to incorporate the changing magnitude, scope and impact of challenges. They need to be able to have the creativity to synthesize a broader range of interdisciplinary knowledge and systems. Engineers need the ability to communicate orally, visually and in written form, as well as listen effectively. Engineers need to be able to communicate with interdisciplinary teams that have globally diverse team members. Other attributes of engineers in the future include the mastering of principles of business and management in business, nonprofit and the government sector. They need to understand the principles of leadership to bridge public policy and technology. The engineers of the future must have the highest ethical standards and level of professionalism. Engineers must also be dynamic, agile, resilient, flexible and lifelong learners. [National Academy of Engineering, 2] It is an incredible challenge to begin to adapt our engineering curricula now, to prepare our engineers for the future. The Industrial Engineering and Management Systems department at the University of Central Florida has accepted this challenge and has already begun to revise and enhance their curriculum to help our engineering graduates acquire the attributes of the engineers of the future. The next section will discuss how the graduate level course, Total Quality Improvement, has been enhanced to help our engineering students acquire the attributes of the Engineer of 2020 VISION.

TOTAL QUALITY IMPROVEMENT COURSE IN THE GRADUATE CURRICULUM

Total Quality Improvement Course Description:

The Total Quality Improvement, ESI 5227, graduate level course provides a broad exposure to topics in quality improvement. [Furterer, 1] The course existed in a different format, but was revised and enhanced to incorporate teaching the Six Sigma DMAIC problem solving approach and allow the students to perform a "real world" Six Sigma project. The course runs for the 16-week semester. The course is intended to focus on the development of tools for the management and improvement of quality in community-based organizations. Essential concepts, practices, and methods of modern quality improvement tools are discussed, along with the Six Sigma DMAIC problem solving approach, and critical success factors to team building and teamwork. Six Sigma team projects are performed by the students applying the DMAIC problem solving approach and appropriate quality tools to help a community-based organization understand and improve their processes and use of technology.

Instructional Strategies:

The course consists of a lecture component that teaches the students in the principles and concepts of Six Sigma and Lean Enterprise. [Brue, 6], [Louis, 7], [Mitra, 8], [Benbow, 9], [Pyzdek, 10], [Wadsworth, Stephens, Godfrey, 11] PowerPoint presentations are used to describe the concepts and provide an understanding of the Six Sigma and Lean Enterprise tools. The DMAIC problem-solving approach is described and case examples are provided to the students. A team-based Six Sigma project incorporates a hands-on service experiential learning opportunity where the students help a community organization improve their processes and use of technology. The course instructor, the author of this paper, serves as a Master Black Belt providing knowledge transfer, advising, facilitation, and mentoring to all of the teams. A Black Belt mentor, assigned to each team, a volunteer from the local Orlando section 1509 professional chapter, provides coaching on the Six Sigma and Lean tools and principles throughout the semester. A certified Six Sigma Green Belt leads or mentors each team. The weekly class is composed of two hours of lecture and one hour of in-class team-based problem solving and team-building activities. Each student spends about 8 to 10 hours per week outside of class on the Six Sigma project activities, for a total resource and mentor effort of approximately 5200 hours across the 16-week semester. The students perform the Define, Measure, and Analyze phases during the semester, and propose improvement recommendations that will be implemented by the client after the semester ends. Control mechanisms and plans are also proposed for later implementation. The assessment of the students' learning includes two individual exams, report presentations and write-ups after the Define, Measure, and Analyze phases, as well as a final report and presentation that include the improvement and control recommendations. The students complete a team assessment to extract lessons learned as well as a 360 degree assessment across the teams to understand the level of effort and commitment of each student on the Six Sigma project. The students share knowledge across the teams by uploading their presentations and reports to a shared website. The project champions also complete an assessment of the value provided by each team to the champion's organization.

Course Map:

An overview of the structure of the course map is presented in figure 1.

The course map describes the principles, activities, tools and deliverables that are covered in the course and are expected to be applied and embraced in the Six Sigma projects. The principles of Six Sigma and Lean Enterprise are taught to the students, including: [Brue, 6], [Louis, 7], [Mitra, 8], [Benbow, 9], [Pyzdek, 10], [Wadsworth, Stephens, Godfrey, 11], [Quality Council of Indiana, 12], [Benbow, Berger, Elshennawy, Walker, 13], [Montgomery, 14], [Besterfield, 15], [AT&T, 16], [Harry, and Schroeder, 17], [George, 18]

- Concepts and definitions of quality, types and impact of variation of processes, the importance and how to define the customers and stakeholders of a process, definition and understanding of a process and its importance to understanding and defining improvements. Empowerment, team building, team-work

- Lean principles of value, value chain, flow and perfection

- Statistical thinking, Statistical Process Control, Design of Experiments, Failure Mode and Effect Analysis

- Measurement, benchmarking, critical to quality, metrics and targets

- Education and training
- Continuous improvement and Kaizen

Figure 1: Total Quality Improvement Course Map

DMAIC Phase	DEFINE	MEASURE	ANALYZE	IMPROVE	CONTROL
Principles	☑	☑	☑	☑	☑
Activities	☑	☑	☑	☑	☑
Tools	☑	☑	☑	☑	☑
Deliverables	☑	☑	☑	☑	☑

The students complete the following activities as part of the DMAIC problem solving approach:

Define: 1) Define the need, 2) identify goals, and 3) form team

Measure: 1) Profile current state, 2) identify problems, and 3) identify root causes

Analyze: 1) Analyze gaps, 2) plan improvements, and 3) define costs and benefits

Improve: 1) Implement solutions, 2) measure impact, and 3) document and train

Control: 1) Define and implement performance measures, 2) continuously improve, and 3) celebrate and reward

Table 1 presents the tools taught and potentially applied in the Six Sigma projects.

Table 1 Six Sigma Tools by DMAIC Phase

Define	Measure	Analyze	Improve	Control
Brainstorming	SIPOC (Supplier-Input-Process-Output-Customer)	Cause & effect analysis	Cost/benefit analysis	One-piece flow
Nominal Group Technique	QFD (Quality Function Deployment)	Waste elimination	Cost of quality	Kanban
Project charter	SWOT	Good Housekeeping	Improvement plans	Visual control
Work plan	Process flow analysis	5S's	Standardized procedures	Continuous improvement
Responsibilities matrix	Benchmarking	Kanban	training	Kaizen
Affinity diagrams	Checksheets	Visual Control	Pull	SPC
Multivoting	Interviewing	One-piece flow	One-piece flow	
Effort/impact grid	Focus groups	Pull		
Simple prioritization matrix	Waste identification			
	Standardization			
	Good housekeeping			
	5S's			
	SPC (Statistical Process Control)			
	Histograms			
	Performance metrics			
	Capability analysis			

The Six Sigma project deliverables describe the components that are expected as a minimum in each report after each phase of the DMAIC problem solving approach. The deliverables are summarized in table 2

Table 2 Six Sigma Project Deliverables by DMAIC Phase

Define	Measure	Analyze	Improve	Control
Project charter	SIPOC	Cause & Effect analysis	Improvement recommendations	Proposed verification of improvements
Customer & stakeholder analysis	Process flows	Summary of problems	Quantification of improvement plans	Control plan
Work Plan	Pareto charts	Summary of data collected	Revised process flows	Team member participation log
Responsibilities Matrix	Critical to quality	Cost/benefit analysis	Procedures	Team assessment survey
Next steps	Key metrics	Cost of quality	Metrics and performance targets	Customer assessment survey
Team members participation log	IFRs (Items for Resolution)	IFRs	Training plans	Significant lessons learned
	Process capability	Next steps	IFRs	Team members participation log
	Next steps	Team members participation log	Team members participation log	
	Team members participation log			

Six Sigma Team Project Descriptions

The Total Quality Improvement course was taught in the fashion described above for the first time in the Fall 2004 semester at UCF. Thirty-one students participated in the course and the Six Sigma projects. Five Six Sigma teams of from five to seven students per team helped organizations improve their processes and how they used technology. Four of the five teams were organizations within the university and the fifth team was a financial services organization who agreed to share the lessons learned from the project to enhance future students' learning. Following are descriptions of the purpose of each team.

Team 1: CECS Graduate Pre-Application Process Improvement Six Sigma Team

The College of Engineering and Computer Science (CECS) at the University of Central Florida recently implemented a pre-application process for students interested in applying for a graduate program in the college. The degree of competition for space in the college's graduate program is increasing. The pre-application process enables the departmental graduate coordinators the ability to review the pre-applicants' qualifications to identify candidates that would be a good match for the respective programs. It also allows the departmental graduate coordinators to waive the application fees of the prospective applicants. This project helped to define improvements to the pre-application process, as well as identify areas for improvement to enhance the technology that is used within the pre-application process.

Team 2: IEMS Front Office Process Improvement

The Industrial Engineering and Management systems (IEMS) department is in the College of Engineering and Computer Science (CECS) at the University of Central Florida. The IEMS department's Front Office staff assists faculty and students with administrative activities, including: budgeting, course scheduling, timesheets and payroll, travel and reimbursement, resource scheduling and appointments, course administration and research project and grant administration. As the department grows, the administrative activities have become more complex. The department had requested that the Six Sigma team assist with process definition and improvement activities related to the Front Office staff's activities and work load balancing.

Team 3: IEMS Graduate Program Process Improvement

The IEMS graduate program has over 250 students and is growing rapidly. The graduate administration process requires high levels of communication, coordination, and transfer of information between departmental personnel, the college and graduate studies. The graduate admission processes include: pre-admission applicant review and decision making, admissions, advising, and students' program of study certification. This Six Sigma project helped to streamline the students' program of study certification process within the IEMS department, as well as helped to define measures to enhance standardization and improve customer (student) satisfaction.

Team 4: Florida Engineering Education Delivery System (FEEDS) Phase 2:

FEEDS is a statewide system whereby engineering courses are delivered both synchronously and asynchronously to industrial sites and cooperating university centers. The ASQ Orlando Section 1509, the UCF Student Chapter, and the Harrington Institute performed a Six Sigma project as part of the ASQ Community Good Works Initiative for the FEEDS system at UCF in 2003 and 2004. The team identified several opportunities for improvement in phase 1. The phase 2 project developed links, procedures, mechanisms, controls and measures between the students, faculty, and FEEDS organization to enhance customer satisfaction.

Team 5: Ocwen Reducing Repeat Calls

Formed in 1988, Ocwen Financial is a vertically integrated multi-billion dollar, publicly traded financial services holding company, and engaged in a variety of businesses related to mortgage servicing, real estate asset management, asset recovery and technology. The Six Sigma project will help to reduce repeat customer calls at their call center in Orlando, Florida. The team analyzed call recordings, defined statistically valid sampling plans, and analyzed the loan servicing system information sample data, to understand the root causes of repeat customer calls. The team identified improvements that will help to reduce the number of repeat customer calls.

The teams successfully performed the Define, Measure and Analyze phases and identified potential improvements and control plans to be implemented by the client organizations after the semester was complete.

MAPPING OF THE ATTRIBUTES OF THE ENGINEERS OF THE FUTURE TO THE TQI COURSE COMPONENTS

Table 1 maps the attributes of the engineers of the future to how the Total Quality Improvement course helps to prepare the engineers for the future. The DMAIC problem solving approach helps the students understand how to solve problems, and learn and adapt tools to many different situations. The team work, and team-building components of the Six Sigma projects help the students to learn how to work on multi-disciplinary diverse teams and treat each other with respect. The teams are required to develop team ground rules and incorporate rules for how they will treat each other, how they will problem solve and be committed to the team effort. The project teams and the problem solving tools help the engineers to apply different tools and to understand why they are using the tools in particular situations. The problem solving tools and team work help them to be flexible, agile, and be receptive to change. The focus on helping community organizations improve their processes provides insight for the teams into how community organizations work and the value that they provide to society. The focus on the voice of the customer and defining the customer with respect to the processes that the teams are improving help the engineers to understand how to focus on the customer and meet the needs of those customers. The case studies and team-based activities help the students better understand and apply the Six Sigma and Lean tools and problem solving methods. The DMAIC problem solving approach helps the teams build strong analytical skills, practical ingenuity, agility, resilience, flexibility and provides opportunities to enhance the ability to synthesize information in a creative manner. The oral presentations and written reports help the students enhance their communication skills. The team leadership and Green Belt opportunities on the project teams help to build the students' leadership skills. The incorporation of the community focus and team work, as well as the association with the American Society for Quality helps the engineers embrace the importance of professionalism and ethical behavior. The entire course provides the opportunity to apply tools for a lifetime, and encourages continual advancement of the engineers' skills and abilities to move them into the future as engineers of the year 2020 VISION.

Table 3 Engineers' Attributes and Total Quality Improvement Course Components Mapping

Attribute of Engineers of 2020	TQI Course Component
How to learn	DMAIC problem solving, case studies
System perspective	System, process, and statistical knowledge
Multi-disciplinary teams	Team building, projects, project management, brainstorming, diverse teams
Flexibility	DMAIC, projects, team work
Receptive to change	Change management, culture change, commitment, communication plan
Mutual respect	Team ground rules, team work, empowerment, reward, recognition, celebration
Social context, community, public policy, global citizen	ASQ Community Good Works initiative focus
Customerization	Voice of Customer, QFD, benchmarking, measurement
Case studies	Local government case study, examples, projects
Strong analytical skills	Problem solving, quality and lean tools, statistical knowledge, process and system focus
Practical ingenuity	QFD, Design of Experiments (DOE), best practices, problem solving
Creativity to synthesize	Critical to quality, process orientation, project and team building
Communication, team work	Team work, team building, reports and presentations, mentoring
Leadership	Team work, mentoring, Green and Black Belt leadership opportunities
Ethical	Quality principles, ground rules
Professional	Association with ASQ, all students must be members
Agility, resilience, flexibility	Practical application on real life problems
Lifelong learning	Entire course

EVIDENCE THAT COURSE OBJECTIVES ARE MET

The course and instructor received extremely high ratings across all of the categories in the university instructor evaluation surveys. The survey uses a rating scale that includes excellent, very good, good, fair and poor. For this course, the students' "overall assessment of instructor" rated 94% of the responses in the excellent, very good and good categories, with 84% of the ratings in the excellent and very good categories. The students rated 94% of the responses in the excellent, very good and good for "facilitation of learning', with 88% of the responses in the excellent and very good categories. The students' ratings in these areas shows evidence that the course objectives were well met.

SUMMARY AND CONCLUSIONS

The Total Quality Improvement course taught in the Industrial Engineering and Management Systems department helps to transfer problem solving knowledge, quality and lean tools and the DMAIC problem solving approach. Many of the students commented at the end of the semester that this course was the best or one of the best graduate courses that they have taken in their graduate career because it helps them to be creative and critical thinkers. The students' evaluation of the instructor provides evidence that the course objectives were well met. Ninety-four percent (94%) of the student ratings fell in the excellent, very good and good rating categories for overall assessment of the instructor, showing high satisfaction with the course. This paper shows that this course is a critical component in the curriculum to help our engineers acquire the attributes and skills to be an engineer in the year 2020.

REFERENCES

[1] Furterer, S.L., Total Quality Improvement, ESI 5227, Course Syllabus, University of Central Florida, 2004.

[2] National Academy of Engineering, *The Engineer of 2020, Visions of Engineering in the New Century*, The National Academies Press, Washington DC, 2004

[3] Evans and Lindsey, The Management and Control of Quality, Sixth Edition, South-Western College Publishing, Cincinnati, OH, 2005.

[4] Evans and Lindsey, An Introduction to Six Sigma & Process Improvement, Southwestern Publishing, Cincinnati, OH, 2005

[5] Joiner, Scholtes, Streibel, The Team Handbook, Third Edition, Joiner, Scholtes, and Streibel, Quality Press, 2003.

[6] Brue, G., Six Sigma for Managers, ASQ Quality Press, 2002.

[7] Louis, R., Integrating Kanban with MRPII: Automating a Pull System for Enhanced JIT Inventory Management, Productivity Press, 1997.

[8] Mitra, Fundamentals of Quality Control and Improvement, 2nd Edition, Prentice-Hall, New Jersey, 2000.

[9] Benbow, D, Kubiak, T., The Certified Six Sigma Handbook, ASQ Quality Press, 2005

[10] Pyzdek, T., The Six Sigma Handbook, second edition, McGraw-Hill, NY 2003.

[11] Wadsworth, H.M., Stephens, K.S., and Godfrey, A. B., Modern Methods for Quality Control and Improvement, 2nd Edition, John Wiley & Sons, New York, NY, 2002.

[12] The Certified Six Sigma Black Belt Primer, Quality Council of Indiana, 2001

[13] Benbow, D.; Berger, R., Elshennawy, A. and Walker, F., The Certified Quality Engineer Handbook, ASQ Quality Press, Milwaukee, WI, 2001.

[14] Montgomery, Introduction to Statistical Quality Control, 3rd Edition, John Wiley, NY, 1997.

[15] Besterfield, D., Quality Control, Third Edition, Simon & Schuster, New Jersey, 1990.

[16] Statistical Quality Control Handbook, AT&T, Delmar Printing Company, North Carolina, 1984

[17] Harry, M., and Schroeder, R., Six Sigma The Breakthrough Management Strategy Revolutionizing the World's Top Corporations., Doubleday, NY., 2000

[18] George, M., Lean Six Sigma Combining Six Sigma Quality with Lean Speed, McGraw-Hill, NY 2002

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