AC 2010-382: CREATION OF A GRADUATE PROGRAM IN ENGINEERING MANAGEMENT: APPLICATION OF BASIC SIX SIGMA PRINCIPLES TO CURRICULUM DESIGN

Anoop Desai, Georgia Southern University

Dr. Anoop Desai received his BS degree in Production Engineering from the University of Bombay in 1999, and MS and Ph.D. degrees in Industrial Engineering from The University of Cincinnati in 2002 and 2006. His main research interests are in Product Lifecycle Management, Design for the Environment, Total Quality Management including tools for Six Sigma and Ergonomics.

Jean-Claude Thomassian, State University of New York, Maritime College

Dr. Jean-Claude Thomassian received his BS degrees in Electrical Engineering and Mechanical Engineering from the University of Toledo in 1992 and 1993, respectively, and MS and Ph.D. degrees in Electrical Engineering from The University of Toledo in 1995 and 2002. His main professional interests are in mixed mode IC design and electrical engineering education; his recent research activity concentrates on symbolic analysis of circuits and MOS models.

Creation of a Graduate program in Engineering Management: Application of basic Six Sigma principles to Curriculum Design

Abstract

This paper presents an educational case study to develop a curriculum in engineering management at a university in the southeast United States. The program is being offered principally at the graduate level, with some courses being offered at the dual level of competency. The courses within the program are offered using the classroom instruction as well as the online format of instruction.

The program content utilizes the various ingredients of Industrial Engineering as well as basic management science and its application to engineering. The newly developed program also takes advantage of audio-visual media to facilitate instruction. The novel aspect of this program is that due to its basic nature, courses are being offered both in the classroom as well as online. This versatile approach makes the program highly lucrative for working professionals as well as distance learners. The paper examines how the basic principles of Six Sigma were systematically applied to curriculum development to not only ensure quality of the program but also to expressly address needs of the students and industry.

Introduction

As engineers, scientists, and technologists advance in their careers, they encounter an increasing expectation of project and team management. At the same time, these technical specialists are oftentimes poorly prepared to take on these additional job responsibilities. A Master of Science in Engineering Management degree is designed to help technical professionals take this next step in their career. In addition to added technical exposure, this well-rounded degree prepares technical professionals to deal with topics such as cost management, world-class manufacturing, workplace safety and ergonomics, leadership, and quality control. A curriculum development effort was recently undertaken at a university in the southeast United States for development of just such a graduate program in Engineering Management. This paper describes the need for the program, its salient features as well as introduces the reader to how basic six sigma principles in applied to curriculum development for the said program.

A degree in Engineering Management is primarily designed for working engineers, technologists, scientists and professionals who are in leadership/management positions or who are planning to advance their careers into the management of technical projects or teams. The curriculum gives students an appreciation of both the technical and managerial perspectives of solving projects. The degree candidate must have an appropriate undergraduate degree in an engineering, engineering technology, manufacturing, or science discipline.

Generally speaking, there are four target audiences for a graduate degree in engineering management. They are enumerated as follows.

1. Non-traditional technical students working to update their credentials and advance in their careers to administrative positions. These students typical have at least 3 years working experience, oftentimes will work full-time while pursuing the degree, and possess an appropriate technical undergraduate degree in engineering, engineering technology, manufacturing, or science.

2. Internal graduates of industrial management, engineering technology, or closely related science programs.

3. Graduates of industrial management, engineering, engineering technology, or closely related science programs from other universities, and

4. International students with a background in industrial management, engineering, engineering technology, or closely related science programs.

The first target audience is considered to be the largest and most viable.

Curriculum Development Methodology

A Six Sigma based design philosophy is used to design the curriculum by means of utilizing tools such as Quality Function Deployment (QFD). This way the needs of various constituencies are addressed. The house of Quality approach enables the streamlining of the process[1] .

The following is a brief introduction to the basic concept of Six Sigma. Most statistical data can be expressed in the form of some kind of normal distribution. The concept of Six Sigma is a concept that seeks to enhance quality [2-4]. This is achieved by ensuring that a substantially large number of the population as expressed by the normal distribution meets or exceeds desired quality levels. That way the number of rejections is minimized and waste is practically eliminated. Why do we use the quantity 6 Sigma? Most data is assumed to be normally distributed in the shape of a bell curve. Assume that the bell curve represents the entire output of a process. The total number of defectives likely to be produced over the long run out of a million parts manufactured is about 3.4 if the entire output falls within six times standard deviation on either side of the process mean. As will be observed, this strategy is readily expandable to the field of academics as well.

<u>What makes the Six Sigma approach different from other approaches:</u>

The objective of using an approach based on six sigma techniques is to find out the specific needs of the market place and try to address those needs effectively. Such an approach significantly improves the employability of students. It imparts a set of marketable skills that can be used in an entrepreneurial sense. In order to accomplish this objective, the aforementioned approach places heavy emphasis on 'how-to' approach of problem solving pertaining to engineering management.

Obstacles to implementation:

Rapid change in marketplace demand constitutes one of the principal obstacles that could be encountered. However, this problem can be easily encountered by placing relative emphasis on fundamental concepts of engineering management. This way, students will be able to grasp concepts clearly. It is clear that such an approach helps facilitate direct and seamless application of skills learned in the classroom to real life situations.

Curriculum Development:

An Engineering management degree is primarily an applied degree that seeks to apply business principles to the management of engineering firms. As such, it is extremely important that the voice of different stakeholders including employers, government organizations and regulatory agencies is incorporated into the curriculum. This can be accomplished through the extensive use of a tool referred to as Quality Function Deployment (QFD).

- Quality Function Deployment:

Quality Function Deployment (QFD) makes widespread use of the so called house of Quality. This is a matrix that converts customer requirements into product design features.

Figure 1 illustrates the structure of a typical house of quality [4].

Customer Requirements		Technical Design Requirements (“HOW’s”) →	Customer Perception
“WHAT’S” ↓	Importance Ranking	Central Relationship Matrix	
Relative Weight			
Competitive Benchmarking			
Target values			

Figure 1: House of Quality

Figure 1 depicts the typical structure of a house of Quality. This is the primary decision matrix used to convert customer requirements into product technical characteristics. Customer requirements are obtained as a result of a thorough and comprehensive market survey. These requirements are listed under the sections entitled ‘What’s’ in Fig. 1. The reader will appreciate that the input obtained from market surveys is data that is of a qualitative nature. It is essential to convert this data into numbers in order to use it for design purposes. This conversion is achieved by the section entitled ‘How’s’ in Fig. 1. The section entitled importance rating rates the relative importance of each customer requirement. The ‘customer perception’ section of the house of quality compares the product/service under consideration with that of the competition.

It will be appreciated that customer requirements can thus be easily be translated into product features using this approach. Simultaneously, it is also useful in ensuring that the product stays ahead of any competition that may exist or might crop up in the future. .

In order to use the QFD systematically, one needs to adopt a four step approach to curriculum design which is detailed as follows.

1. **Curriculum Planning:** This is the first step in the process. It seeks to incorporate the voice of the customer into curriculum design. This is important for students graduating with an engineering management qualification to have any future in terms of employability at all. Incorporation of this step in the design process ensures proactive design decisions. It is akin to asking the question: ‘What outcome do you expect out of this course?’ Opinions expressed are then gathered together and arranged from highest priority to lowest priority. This is accomplished by assigning numeric scores ranging from 1-10 to each.
   The principal tool used for step 1 is the house of quality. This is described in detail in the preceding paragraphs and is depicted graphically in figure 1. One starts the process with developing questionnaires to be circulated amongst different stakeholders. The objective of questionnaires is to ascertain the stakeholders’ preferences and expectations from the program. Once a thorough list of customer expectations is obtained, the program designers can then set about trying to convert said requirements into design features for the program.
   The principal requirement of design features is that they be measurable. It is not sufficient to have a vague definition of design characteristics. By their very definition, design characteristics should be quantifiable. For instance, if a particular customer requirement stated that students graduating from the program have a thorough understanding of Materials Requirement Planning (MRP), then the corresponding design requirement could be developed as “Knowledge of Scheduling principles”. The output from this stage can then be carried over to the next stage of the QFD process.

Figure 2 depicts the curriculum planning phase of the 4 step QFD approach. The interrelationship between customer requirements and curriculum design features is assigned a numeric score (3, if the interrelationship is very strong, 2 is it is medium, 1 if it is weak and 0 if it is nonexistent). The row total is obtained by adding up scores of the interrelationships for each row and multiplying that number by the score assigned to importance for that row.

Curriculum Design Features (HOWs)-------------------------------		Exit survey results post taking an advanced course in project scheduling	Exit survey results post taking a course in Advanced Engineering Economics	Exit survey results post taking an advanced course in Optimization	Exit survey results post taking a graduate level course in Design for 'X'	Exit survey results post taking a graduate level course in Organizational Management	Exit survey results post taking a n advanced course in Workplace safety and Hazard Analysis	Row Total
Customer Requirements (WHATs)	**Importance**							
Need to have a thorough understanding of Scheduling principles	**10**	3	0	2	0	0	0	60
Need to understand the basic and advanced principles of Engineering Economy	**9**	0	3	0	0	0	0	27
Need to have a thorough understanding of optimization principles	**10**	1	0	3	0	0	0	40
Need to be familiar with engineering design principles such as Design for manufacturing and DfX	**6**	0	1	1	3	1	1	42
Need to be thoroughly conversant with software packages such as Excel Solver and LINDO	**7**	0	0	3	0	0	0	21
Need to be conversant with management and employee motivation principles	**7**	1	1	1	1	3	3	70
Need to be familiar with principles related to organization structure	**6**	0	0	0	1	3	2	36
Need to be familiar with issues pertaining to workplace safety and workplace hazards	**6**	0	0	0	1	2	3	36
Column Totals		47	40	84	37	57	57	

Figure 2: House of Quality for Converting Customer Requirements into Curriculum Design Features: Conceive

It is clear from Fig. 2 that most stakeholders required graduates of the program to be conversant with scheduling principles, and optimization principles. This is reflected in those customer requirements obtaining a numeric score of 10 points each.

Successive iterations of the QFD are performed in order to convert product planning into the quality control matrix as depicted in Fig. 3. The entire sequence is not being depicted here for reasons of space. However, it will be discussed in detail at the conference.

2. **Component Deployment**: Once customer needs have been ascertained, it is essential to break them down into manageable portions. Each portion represents a characteristic of the curriculum. For instance, a customer requirement such as 'understand economics of engineering project management' could be translated into components such as 'knowledge of finance', ' knowledge of engineering economy', 'knowledge of scheduling principles' etc. It also tries to find out how many credit hours need to be assigned to each course.

3. **Instruction Planning:** This step identifies the resources and methods needed to impart education and training conforming to customer requirements. This includes qualifications of instructors, experience teaching same or similar courses, relevant work experience in the field etc.

4. **Quality Control:** This is the final step in the design of the curriculum. It tries to identify the minimum level of knowledge every student with a degree in engineering management is expected to have.

The four step approach of the QFD in a typical manufacturing scenario is depicted in Fig. 3.

	Measurable Objectives		High level Design-I		Methods and Tools		Procedures adopted
Customer Voice	Product Planning (Phase I: Conceive)	Measurable Objectives	Design Planning (Phase II: Develop)	High Level Design - I	Planning of the Process (Phase III: Manufacturing)	Methods and Tools	Production Planning (Phase IV: Delivery)

Figure 3: The Four Step QFD in a Typical Manufacturing Scenario

As will be appreciated from Fig. 3, the 'conceive' step corresponds to 'curriculum planning', 'develop' phase corresponds to 'component deployment', 'manufacture' phase corresponds to 'instruction planning' and 'deliver' phase corresponds to 'quality control'.

- <u>Continuous improvement through Ishikawa and Pareto Analyses:</u>

This stage of the methodology seeks to identify and eliminate these obsolete traits that may become part of the curriculum as time progresses by using Ishikawa analysis and Pareto analysis.

Ishikawa analysis is characterized by the cause and effect relationship that underlies most non-conformity. Once the defect in instruction or student learning is addressed, Pareto Analysis can be applied so as to achieve further improvement of course content and instruction methods.

Ishikawa analysis [4] is also referred to as cause and effect analysis or the fishbone diagram. It is illustrated in Fig. 4.

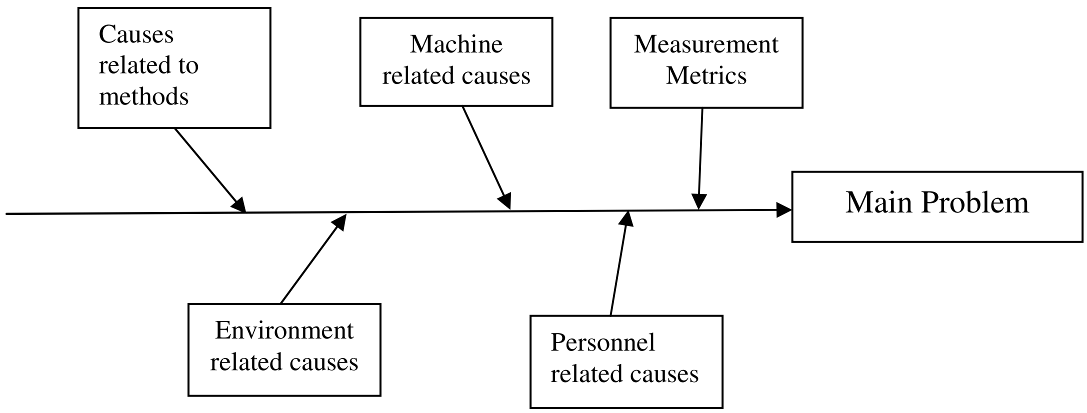

Figure 4: Ishikawa Analysis

Pareto analysis constitutes a problem solving tool which tries to pin point the most important defect and obtain solutions to solving it. It has been observed that 80% of all defects can be traced back to 20% of all causes. A Pareto analyst seeks to focus on those 20% causes (minority of causes) that are responsible for majority of defects.

Once a program curriculum is developed, it needs to be continuously checked for relevancy and revised and updates accordingly. The aforementioned tools for continuous improvement are used for this purpose. It should be noted that both the Pareto analysis and Ishikawa analysis need to be used in conjunction for optimal results. We are unable to present and detailed findings of this technique at the moment since the curriculum has been in effect for just over a semester. Continuous improvement and anomaly rectification can occur after once the curriculum has been in place for a considerable period of time and defects have had an opportunity to creep in. An example is cited below.

It is possible that over time, the ability of students to solve complex optimization problems could become impaired. In most cases the cause of this could be traced back to limited problem solving practice and/or over reliance on software packages to solve such problems. This root cause can be identified using the fishbone diagram analysis method. The problem can be easily solved by ensuring a certain level of rigor in terms of variety of problems solved in class as well as exposure to paper-pencil techniques of problem solving. It can also be rectified by ensuring that students get an adequate amount of problem solving practice through in class assignments and homework problems. This line of reasoning is depicted in Fig. 5. Fig. 5 graphically depicts the problem solving approach typically resorted to in Ishikawa analysis.

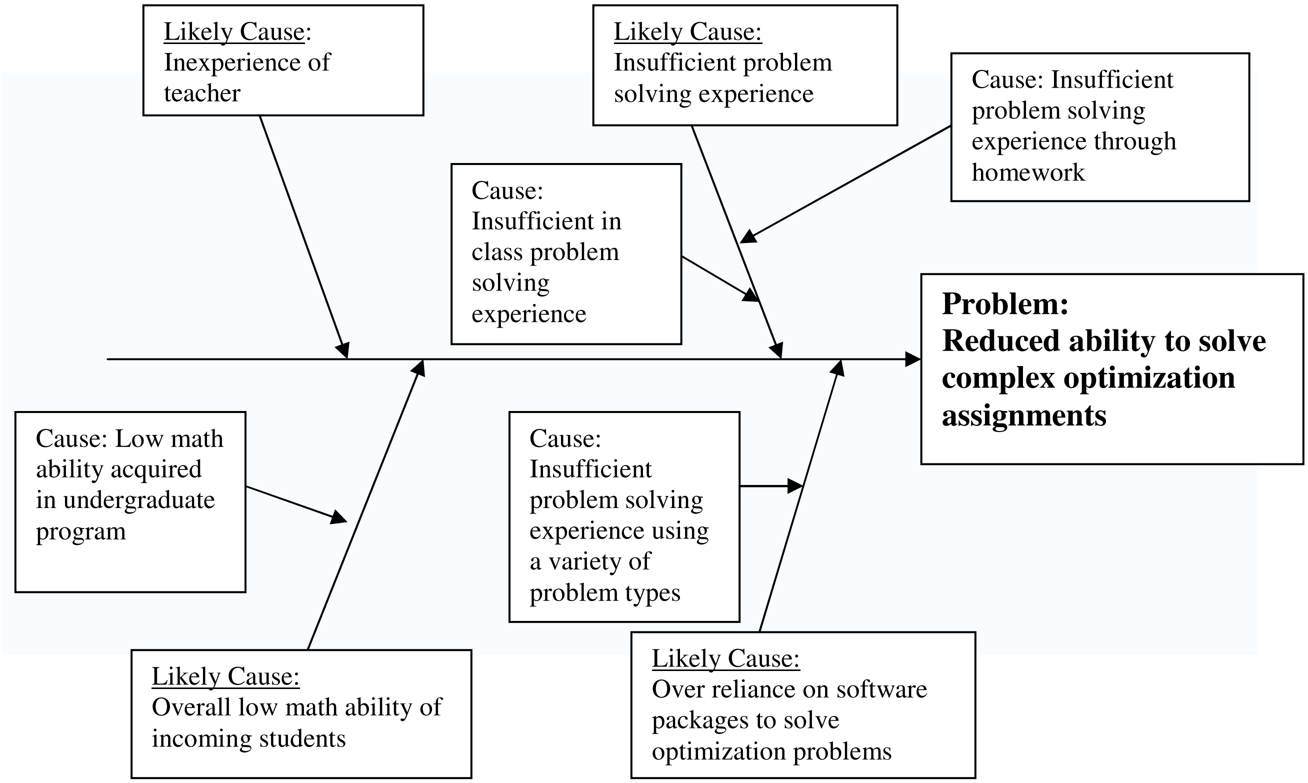

Figure 5: Application of Ishikawa Analysis to Identify Causes of Major Problems

The Six Sigma methodology enables staying one step ahead of the competition

The Six Sigma methodology presented in this paper enables staying ahead of the competition in academia due to the following reasons:

- To start out, the curriculum is built with the end customer in mind. It is not built based on what the academics think students should learn. Rather, it incorporates the different skills that are relevant in the workplace and future employers think students should possess in order to be successful. This approach by itself makes the Six Sigma methodology unique in approach.

- The ranking of customer requirements enables curriculum designers to weigh the pros and cons of incorporating different courses and learning methods into the curriculum with a single question in mind: "How would this affect the future career prospects of graduates?" This approach enables assigning incremental value to each program attribute and this value can change with customer requirements thus making the program as a whole highly flexible.

- Due to techniques built in to the design to ensure continuous improvement, the program structure is always subjected to thorough reviews and modifications if need be. These modifications are ultimately a function of customer requirements (employers) and therefore influence the career prospects of graduates in a positive manner. Positive impressions made on employers are bound to give rise to virtuous cycle in terms of students' recruitment in the future and enhanced brand image for the program.

The design methodology discussed in the preceding pages is graphically presented in Fig. 6.

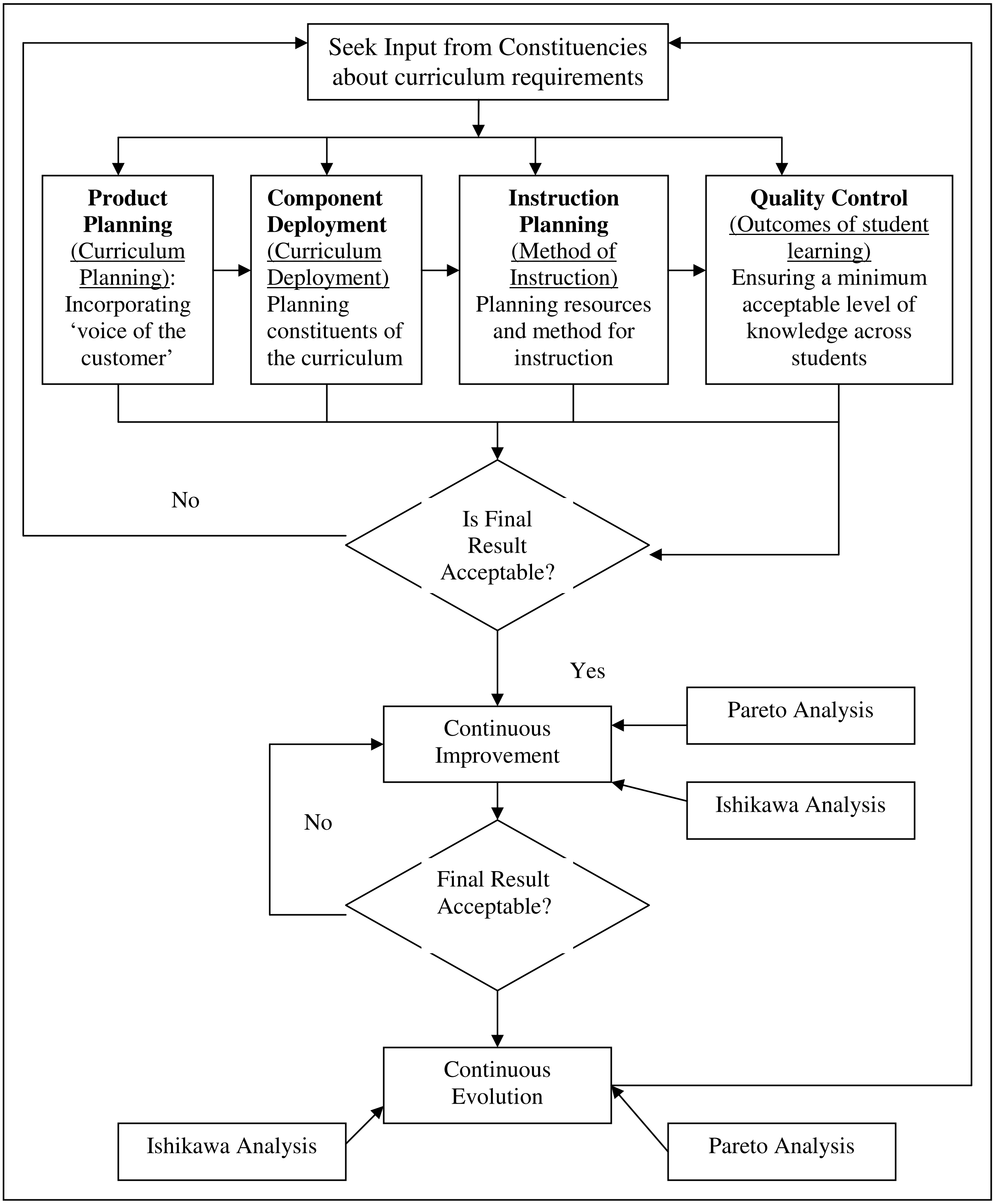

Figure 6: Six Sigma Principles in Curriculum Design Methodology

Final Curriculum

Different stakeholders including employers, professional societies, accreditation boards etc were consulted for input in terms of their expectations from students graduating from the course. Said stakeholders represented a wide spectrum of interests. Meetings took place over the course of a month and a half. Consensus was often difficult to reach. Conflict of interest was generally resolved based on the employability as well as project management factors.

The Engineering management program objectives were identified as follows:

1. Create a viable graduate degree for technically trained professionally as they enhance and expand their credentials to meet the growing administrative and leadership expectations of their employer.

2. Create a curriculum that while rigorous, still remains attractive to non-traditional graduate students. This includes offering thesis and non-thesis tracks, scheduling courses convenient to the students (afternoons, evenings, and three sessions), and requiring a minimum number of credits (30 for both thesis and non-thesis tracks). As the degree program matures, it may be possible to offer a significant component by distance learning technology.

3. Create a pool of students that will compliment and stimulate the professional development of our faculty as teacher-scholars.

4. Contribute to the university's mission, while enhancing the university's reputation

The final curriculum is presented in table 1for non-thesis track.

Table 1: Curriculum in Engineering Management: Non Thesis track

Curriculum For A Master of Science in Engineering Management—Non Thesis Track	
A. Foundation Courses	
1. TCGT 7532 Global Technology	3 credits
2. TCGT 7230 Industrial Case Study	3 credits
B. Essential Skills	
3. FINC 7231 Financial Problems ACCT 7230 Accounting for Executives ACCT 7134 Analysis and Reporting	Choose 1 for 3 credits
4. STAT 6130 Statistics for Researcher	3 credits
5. TMET 7xxx Numerical Methods for Engineers	3 credits
C. Management Skills	
6. TMFG 5433 World Class Manufacturing	3 credits
7. TCGT 7330 Leadership and Motivation	3 credits
8. TSEC 5331 Occupational Safety and Health	3 credits

D. Technical Exposure	
9. TMET 5xxx/G Automation and CIMS TMET 5xxx/G Mechanical Controls TEET 5xxx/G Electrical Controls TMET 5xxx/G Vibration and Preventative Maintenance TEET 5xxx/G Industrial Electronics TMET 5xxx/G Finite Element Methods Directed Study or an Advisor Approved Technical Electiv	Choose 1 for 3 credits
E. Capstone Activity	Choose 1 for 3 credits
10. TMET 7xxx Internship (required if lacking a minimum of 3 yrs professional experience) TMET 7xxx Management of a Capstone Project TMET 7xxx Directed Project	
TOTAL	30 credits

Table 2 depicts the curriculum for the thesis track for the same program.

Table 2: Curriculum in Engineering Management: Thesis track

Curriculum For A Master of Science in Engineering Management—Thesis Track	
A. Foundation Courses	
1. TCGT 7532 Global Technology	3 credits
2. TCGT 7530 Research and Technology	3 credits
B. Essential Skills	
3. FINC 7231 Financial Problems ACCT 7230 Accounting for Executives ACCT 7134 Analysis and Reporting	Choose 1 for 3 credits
4. STAT 6130 Statistics for Researchers	3 credits
5. TMET 7xxx Numerical Methods for Engineers	3 credits
C. Management Skills	
6. TMFG 5433 World Class Manufacturing TSEC 5331 Occupational Safety and Health	Choose 1 for 3 credits
7. TCGT 7330 Leadership and Motivation	3 credits
D. Technical Exposure	
9. TMET 5xxx/G Automation and CIMS TMET 5xxx/G Mechanical Controls or TEET 5xxx/G Electrical Controls TMET 5xxx/G Vibration and Preventative Maintenance TEET 5xxx/G Industrial Electronics TMET 5xxx/G Finite Element Analysis Directed Study or an Advisor Approved Technical Electiv	Choose 1 for 3 credits

E. Capstone Activity	
10. Thesis+ (+ Must have close industrial project contact/internship if lacking 3 years professional experience)	6 credits
TOTAL	30 credits

Conclusion

A methodology to apply principles of Six Sigma and quality improvement to the field of academics was demonstrated in this paper. We intend to keep updating the curriculum as how important changes will need to be made with the development of future scenarios and technologies. However, it has been demonstrated that considerable streamlining of the process of curriculum development can be achieved by the application of six sigma principles to said process.

References

1. Akao, Y(ed), *Quality Function Deployment*, Cambridge, MA: Productivity Press, 1990
2. Mizuno, S, *Companywide Quality Control*, Tokyo: Asian Productivity Organization, 1988
3. Shingo, S, Zero Quality Control: *Source Control and the Pokayoke system*, Cambridge, MA, Productivity Press, 1986
4. Harry, M.J., and Schroeder, R, *Six Sigma: The Breakthrough Management Strategy Revolutionizing the World's Top Corporations*, Doubleday Business, 2006.