AC 2010-381: CREATION OF A GRADUATE PROGRAM IN SAFETY ENGINEERING: APPLICATION OF BASIC SIX SIGMA PRINCIPLES TO CURRICULUM DESIGN

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Creation of a Graduate program in Engineering management with a concentration in Safety Engineering: Application of basic Six Sigma principles to Curriculum Design

Abstract

This paper presents an educational effort to develop a curriculum in engineering management with a concentration in safety engineering at a university in the southeast United States. This program is offered both at the graduate level as well as some courses being offered at the dual level. Both online learning as well as classroom learning is adopted to maximize outreach and address the needs of a growing population of students.

Safety and hazardous waste management constitute the two principal pillars of program development. This paper presents an overview of the curriculum. It also examines the application of Six Sigma principles to curriculum development. This was done in order to ensure quality of the program and to expressly address needs of students and industry.

Introduction

A Master of Science in Engineering Management degree is designed to help technical professionals take the next step in their careers as they 'graduate' to a management oriented career. Such a degree prepares technical professionals to deal with topics such as cost management, world-class manufacturing, workplace safety and ergonomics, leadership, and quality control. This paper deals with a curriculum development effort which was recently undertaken at a university in the southeast United States for development of a concentration in safety engineering.

Any degree in engineering management with a concentration in safety engineering is generally found to be targeted towards principally four kinds of audiences. The first type of audience constitutes professionals and graduate students who have a background in Safety Engineering, Ergonomics, Industrial management, engineering, engineering technology program graduates from universities across the United States. We thought it imperative that our program be able to serve not only local community and regional students, but cater to the needs of the country as a whole. The second group constitutes international students with a background in industrial engineering, engineering technology, safety engineering, workplace management etc. This way, greater exposure can be gained in terms of not only expertise but the program can be enriched by means of varied types of experience. Technical students who are working in order to gain higher credentials in order to advance in their careers to administrative positions constitute the third category of potential students. These students generally tend to have anywhere from about 3-5 years work experience on average before they join the program. Finally, Internal graduates of our own undergraduate programs in the areas of industrial management and engineering technology round off the universe of potential students.

Developing the curriculum

Substantial process streamlining was achieved by the adoption of a three pronged Six Sigma methodology when developing the concentration in Safety Engineering. Quality Function Deployment (QFD) was the basic tool used said process.

The concept of Six Sigma seeks to enhance quality[2-6]. 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. This leads to almost complete elimination of waste in all forms. It is often asked what is so special about six times Sigma. Why six and not any other number? In a normally distributed data set, 99.7% of the normal distribution lies within 3 standard deviations on either side of the mean. That means that the total population falling within those bands corresponds to 6 times standard deviation (Sigma). This strategy which has been highly advantageous in manufacturing and service organizations can be effectively extended to academics as well.

While other approaches to curriculum development often mimic what has already been done or put into practice earlier, a quality based approach significantly improves the employability of students. It imparts a set of marketable skills that. In order to accomplish this objective, the aforementioned approach places heavy emphasis on 'how-to' approach of problem solving pertaining to safety engineering in this particular situation.

The concept of safety management is more or less universal in nature. The kinds of accidents an employee in any kind of workplace situation could be exposed to have been extensively studied over the years. The only obstacle to implementation could result if an entirely new kind of cause for accidents were to emerge, which in the authors' opinion is highly unlikely. If even if such an event were to occur, the curriculum places heavy emphasis on fundamental concepts related to workplace safety. This way, students will be able to grasp concepts clearly. This enables seamless application of skills learned in the classroom to real life situations which could be a life saving skill in the workplace in the context of safety engineering.

<u>Curriculum Development:</u>

A concentration in safety engineering primarily deals with making the workplace a safe environment for workers. It is obvious that it take into account voices of customers, safety regulations, and government guidelines to workplace safety etc. A Six Sigma tool named Quality Function Deployment (QFD) helps us accomplish this objective

- <u>Quality Function Deployment:</u>

Quality Function Deployment (QFD) uses a matrix that converts customer requirements into product design features. This matrix is referred to as the house of quality

Figure 1 illustrates the structure of a typical house of quality.

<table>
<tr><td colspan="2">Customer Requirements</td><td>Technical Design Requirements</td><td rowspan="2">Customer Ratings</td></tr>
<tr><td>Details</td><td>Importance Ranking</td><td>Central Relationship Matrix</td></tr>
<tr><td colspan="2">Technical Ranking</td><td></td><td rowspan="3"></td></tr>
<tr><td colspan="2">Technical Rating</td><td></td></tr>
<tr><td colspan="2">Target value</td><td></td></tr>
</table>

Figure 1: House of Quality

The following four steps are followed when using the QFD approach in a systematic fashion.

Step 1: Planning the curriculum to meet customer demands: This is the first step of the 4 phase QFD. It tries to ascertain the needs of the customer. The customer in this case is a wide body of constituents ranging from students, government agencies, employers, safety regulators etc. It focuses on making students graduating with a safety engineering qualification employable. This step tries to ascertain what outcomes stakeholders expect out of the program. Opinions expressed are generally qualitative in nature. However, before we can proceed, this qualitative data has to be converted to quantitative data. This is accomplished by arranging customer priorities from highest priority to lowest priority. Highest priority is given a numeric score of say 10 and lowest is given a score of say 1.

Step 2: Component Deployment to accomplish curriculum design: Customer needs are broken down into manageable portions using the second step of the 4 step QFD. For instance, a customer requirement such as 'understand hazardous waste management' could be translated into components such as 'knowledge of chemical and biological hazards', ' knowledge of waste management', 'knowledge of OSHA guidelines' etc. The other objective of this step is it assigns credit hour requirements to individual courses.

Step 3: Instruction Planning to facilitate course delivery: As the name suggests, instruction planning strives to plan for instructional requirements. This includes consideration of details such as individual course structures, instructor qualifications and experience, provision of real life case studies and co-op opportunities to enhance the learning experience etc.

Step 4: Quality Control to ensure uniformity across course and section content: Quality control constitutes the end result of all QFD activities. Once, the curriculum and individual courses have been designed, it is important to ensure that all constituents meet or exceed specific quality needs as expressed by the customer in stage 1. The basic objective of this stage is to ensure the minimum knowledge base for all students with a certificate in safety engineering.

The first stage of the 4 step QFD approach is depicted in Fig. 2. All customer requirements are listed under the "What' section of the house of quality. The main objective of using the house of quality approach is to convert subjective customer requirements into measurable objective program outcomes to enable comprehensive curriculum design (listed under the 'How' section of the QFD). There is a correlation between customer requirements and curriculum design features. For the sake of this study, a score of 3 was assigned to the interrelationship, if it was very strong, 2 is it was medium, 1 if it is weak and 0 if it is nonexistent). The total for each row was obtained by multiplying the sum of interrelationship scores for each row and multiplying that number by the corresponding importance ranking for that particular row.

Successive iterations of the house of quality as presented in Fig. 2 are performed in order to establish a correlation between customer requirements as the input and quality control as the final output. Due to space limitations, the entire sequence is not being discussed in these pages.

Curriculum Design Features (HOWs)-------------------------------		Exit survey results post taking an advanced course in system safety	Exit survey results post taking a course in hazardous waste management	Exit survey results post taking an advanced course in Occupational Safety	Exit survey results post taking a graduate level course in Environmental management	Exit survey results post taking a graduate level course in Environmental Law	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 workplace hazards	**9**	3	0	2	0	0	3	72
Need to understand the principles of hazardous waste disposal and storage	**10**	0	3	0	2	2	0	70
Need to have an appreciation for workplace accidents, causes and preventive measures	**10**	2	0	3	0	0	3	80
Need to be familiar with principles related to the safety of overall systems	**8**	3	1	2	0	1	2	72
Need to be thoroughly conversant with occupational hazards and safety of related systems	**8**	0	0	3	2	0	3	64
Need to be conversant with principles of environmental safety	**6**	0	2	0	3	3	0	48
Need to be familiar with principles related to safety in public spaces	**7**	1	0	0	1	0	0	14
Column Totals		78	50	88	61	46	97	

Figure 2: The Conceptualization Stage of the Four Step QFD: Converting Customer Requirements into Measurable Program Outcomes Using the House of Quality

- <u>Continuous improvement of curriculum through implementation of Ishikawa and Pareto analyses:</u>

Ishikawa analysis is also called a Cause-and-Effect or Fishbone Diagram. It is generally used to pinpoint the defect in student learning and curriculum design as well as identify the main cause of that defect. Pareto Analysis is used in order to enhance content. A program curriculum needs to be in a constant change of continuous improvement in order to remain relevant. This is especially true in the case of a professional program. Tools such as Ishikawa analysis (also referred to as the fishbone diagram) in conjunction with Pareto analysis are used to accomplish improvement on an ongoing basis. Readers should note that said curriculum has been in place for just over one semester. As such, in the authors' opinion, not enough time has elapsed to allow for discrepancies to creep into the curriculum structure. Defects generally creep in over time. Thus it should be noted that continuous improvement and anomaly rectification can take place after at least a few semesters have passed since a new program was adopted.

An example of Ishikawa analysis as applied to pinpointing the root cause of a defect in instruction is illustrated in Fig. 3.

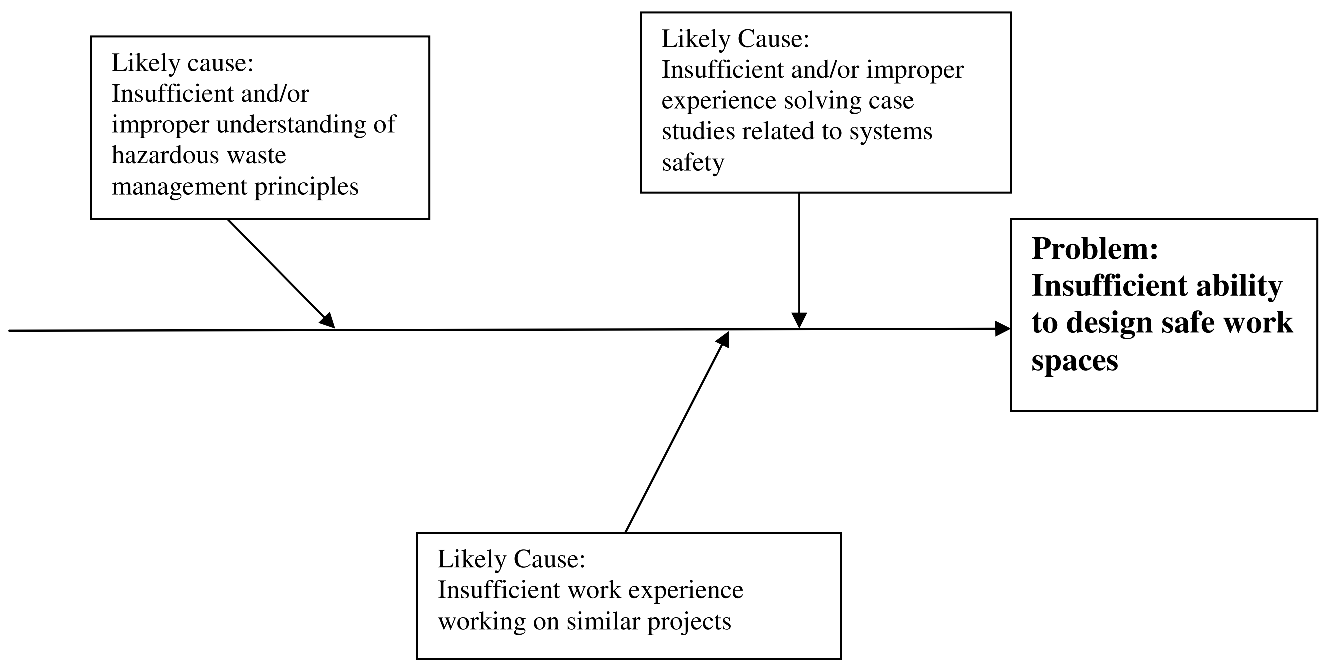

Figure 3: Ishikawa Analysis as Applied to the Curriculum Development Process

A close observation of workplace accidents will reveal that most accidents are caused by a few errors either on part of the worker or due to environmental conditions. In any case, it has been established that most defects in any product or in this particular case, most (to the tune of almost 80%) accidents have their root cause in a very few number (about 20% approximately) of causes. This is the backbone of Pareto Analysis. Instead of wasting time and resources on random causes, this methodology tries to identify common causes that are responsible for most defects.
Pareto analysis is an important tool in the Six Sigma toolbox because it saves time, effort and resources in problem identification.

The design methodology is presented in Fig. 4.

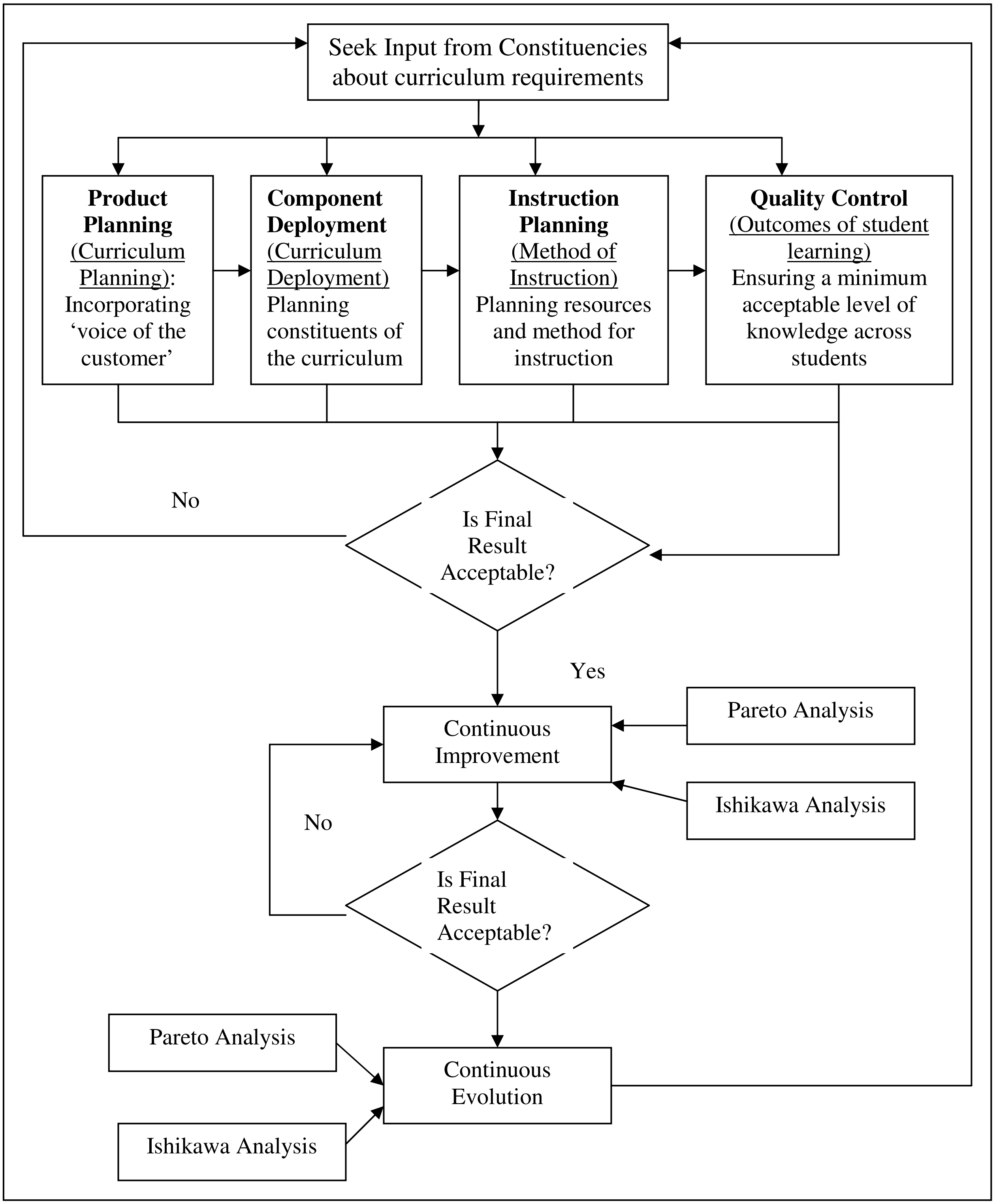

Figure 4: Six Sigma Principles in Curriculum Design: Methodology

Final Curriculum

The result of consultations with companies, employers, government organizations and regulatory bodies was gathered and subjected to the methodology presented in the preceding pages.

The Safety Engineering concentration objectives were identified as follows. Firstly, it was expected to create a viable graduate degree for engineers as they begin to assume leadership positions in the general area of safety and workplace compliance and management. Secondly, a rigorous curriculum that is attractive to students pursuing a graduate degree while working full time was also expected. In order to accomplish this objective, it was recognized that a substantial number of courses might have to be offered via distance learning methods. The final objective dealt with the overall fit of the program within the university structure. It was expected that the new program should contribute to the university's mission, while at the same time strived to enhance its reputation.

The graduate certificate in Occupational safety and environmental compliance would require a total of 12 semester credit hours. This includes 6 semester hours of required courses and 6 semester hours of restricted electives. The structure is as follows:

<u>Required Courses:</u>

TSEC 5331G	Occupational Safety (3hrs)
TSEC 5336G	Environmental Law (3 hrs)

<u>Restricted Electives (Choose two courses)</u>

TSEC 5333G	Industrial Hygiene and Ergonomics (3 hrs)
TSEC 5334G	Hazardous Waste Management (3 hrs)
TSEC 5335G	Systems safety in Manufacturing (3 hrs)
PBAD 7337	Environmental management and Policy (3 hrs)
PBAD 7632	Public Safety Management (3 hrs)
PUBH 8132	Environmental and Occupational Health (3 hrs)

Conclusion

Safety Engineering is a field of study and practice that has been around for some time now. There are numerous programs around the United States that offer degrees and certificates in safety and workplace compliance. Most of these programs however have not been updated in a while and thus don't necessarily address contemporary needs. We have resorted to a different approach to curriculum design that not only addresses today's needs, but is dynamic enough to keep changing and evolving with the times. This principle has been amply demonstrated in this paper.

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