

The Adaptation of Six Sigma Methodology to the Engineering Education Enterprise

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Abstract

Six Sigma is a proven methodology for improving business processes by using statistical methods to identify and reduce process variation. The Six Sigma program popularized by Motorola in the early 1980s extended the quality tools that were part of the Total Quality Management movement by adding an emphasis on financial accountability. Six Sigma quality improvement techniques have also been successfully applied in the service sector and, very recently, in the education enterprise. This paper describes a proposal to adapt the Six Sigma process improvement methods that have been shown to be successful in the business enterprise to the engineering education enterprise at Mercer University. Our implementation of Six Sigma will involve a systems approach to problem solving and emphasizes the three C's: common metrics, constant communication, and culture change. One of the proposed projects was recently funded by the Engineering Information Foundation and is currently underway.

Introduction

Six Sigma is "a comprehensive and flexible system for achieving, sustaining and maximizing business success. Six Sigma is uniquely driven by close understanding of customer needs, disciplined use of facts, data, and statistical analysis, and diligent attention to managing, improving, and reinventing business processes" (Pande, Neuman, and Cavanagh, 2000, p. xi). Six Sigma projects have been shown to improve business processes by using statistical methods to identify and reduce process variation. In addition, the Six Sigma philosophy recognizes the need to tie project implementation and project completion the financial needs of the company.

The Six Sigma program popularized by Motorola in the early 1980s extended the quality tools that were part of the Total Quality Management movement by adding an emphasis on financial accountability (Bossert, 2003). The Six Sigma process was further refined and popularized by Jack Welch at GE in the late 80s and early 90s. Motorola's efforts were recognized nationally when they won the prestigious Malcolm Baldrige National Quality Award (MBNQA) in 1988 (Bhote, 2002). The MBNQA was originally established by Congress in 1987 to recognize excellence in quality efforts in manufacturing. Motorola was the first company to win the MBNQA. Since that time, a number of other businesses have won the award. Awards are given in manufacturing, service, small business, and, starting in 1999, education and health care (Malcolm Baldrige National Quality Award, 2003). A review of MBNQA winners indicates that Six Sigma quality improvement techniques have also been successfully applied in the service sector and, very recently, in the education enterprise.

Now in the year 2004, Six Sigma initiatives have been credited with increasing productivity and profitability at numerous companies in the business sector. We propose to adapt the Six Sigma process improvement methods that have been shown to be successful in the business enterprise to the engineering education enterprise at Mercer University.

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Our implementation of Six Sigma will involve a systems approach to problem solving and emphasizes the three C's: common metrics, constant communication, and culture change. Pande (2000) describes the potential benefits of the Six Sigma approach:

- Cost reduction
- Productivity improvement
- Market share growth
- Customer retention
- Cycle-time reduction
- Defect reduction
- Culture change
- Product/service development

These benefits can be translated to the educational environment if we view the production of a qualified engineering graduate as the result of a defect free process. Issues of customer retention (students are the customers), cycle-time reduction (students graduate in the shortest possible time), and market share growth (the number of graduates from the school of engineering increases) have direct application to the engineering education enterprise. Since students pay to participate in the education process, process improvement that results in a reduction in the amount of time needed to successfully complete degree requirements will result in a cost reduction for the student. Thus our project goal would be to increase the number of students who meet the qualifications for graduation from the school of engineering and to help the students meet these requirements in the shortest possible time.

Project Descriptions

At this time it is impossible to state the exact nature of the projects that will be implemented, since selection of specific Six Sigma projects will be conducted by the Six Sigma team. However, the project director has identified several potential projects based on research conducted at Mercer University over the past two summers.

Project 1: Success in Entry Level Mathematics Classes

Calculus is one of the building blocks of the engineering curriculum. Student performance in calculus has been a source of concern of faculty and administrators for many years. Attempts to improve the situation have had mixed results. A recent report from the associate dean's office indicates that the "unsuccess rate" (earning a D, F, or W) in calculus is still alarmingly high. Fewer than half of the students enrolled in calculus earn an A, B, or C the first time they enroll in the course. In Six Sigma terms, inability to earn an A, B, or C in calculus may be classified as a defect of the acquiring calculus knowledge process. The interim process yield would be calculated as the number of students who earn an A, B, or C divided by the number of students who originally enrolled in the course. Historically, this process has been running at very low sigma levels (less than two sigma) and there is much room for improvement. Relatively high sigma levels indicate a very low defect rate, in which less than 1% fail calculus. The ultimate goal of this Six Sigma project would be to raise student performance in calculus to higher sigma levels.

Project2: Identification of Student Attitudes Associated with Persistence

For three years, Mercer University participated in a cross-institutional study designed to assess engineering freshman student attitudes as they relate to persistence in the engineering curriculum. Results indicate that at some schools, men's and women's levels of confidence with respect to math, science, and engineering differ statistically (Besterfield-Sacre, Atman, and Shuman, 1997) and that these differences may have negative implications for staying in engineering. We propose to conduct a data mining project in which we will conduct statistical analyses to determine critical-to-quality factors that differentiate the attitudes of freshmen who persisted in an engineering

curriculum at Mercer for at least two years with those who transferred to a different school at Mercer (College of Liberal Arts or Stetson School of Business) by the beginning of their third year of college attendance.

Project 3: Stories of Success for Women Engineering Students

Data for 1991-2001 first-time full-time engineering freshmen (FFEF) indicate that on average, one third of the entering freshman class is female. Nationally, on average the percentage of women is closer to 20 %. There is evidence that the Mercer environment results in a higher than average academic success rate for women engineering students. The most recent statistics from the ASEE Profile of Engineering Schools indicate that Mercer's School of Engineering was ranked 8th in the nation in percentage of women bachelor degree earners for 2002. The application of Six Sigma Voice of the Customer (VOC) techniques could yield significant insights into the institutional factors and student characteristics that resulted in this successful outcome for women. In a national survey of 19000 women engineering students at 53 schools, Goodman, et al. (2000, p. 82) observed that, in universities where engineering students comprise a larger percentage of the undergraduate population, the engineering graduation rate is higher. By benchmarking with carefully selected schools, we can investigate the hypothesis that the graduation rate for women is higher at schools which have high proportions of women students. The initial qualitative study will be based on research methodology developed by Seymour and Hewitt (1997). A random sample of engineering persisters will be surveyed. The interviews will be semi-structured and loosely based on the survey questions that were used by Seymour and Hewitt (1997, pp. 401-402).

Project 4: Determination of the Threshold Path Toward an Engineering Degree

In 1998, the United States Department of Education (DOE) published a significant quantitative study of engineering persistence conducted by Clifford Adelman, Senior Research Analyst for the DOE. Adelman's monograph, "Men and Women of the Engineering Path: A Model for the Analysis of Undergraduate Careers", reports on an empirical study of a national college transcript sample. The research design included the development of tentative decision rules for classifying students as well as a preliminary taxonomy. His research was supported by the National Science Foundation and the United States Department of Education. Adelman's analysis of the curricular path taken by successful engineering students is similar to the concept of process mapping that is an essential component of the Six Sigma philosophy. Project 4 would involve developing process maps for successful engineering students. By analyzing curricular paths for unsuccessful engineering students, and comparing them with paths of successful engineering students, we can begin to document best practices (an established Six Sigma technique).

Project Implementation and Completion

Pande, et al. (2000) describe three criteria for the selection of Six Sigma projects:

- There is a gap between current and desired/needed performance.
- The cause of the problem is not clearly understood.
- The solution isn't predetermined, nor is the optimal solution apparent.

We believe that the aforementioned potential projects meet these criteria, and would like to conduct all four, resources permitting. Recalling that the Six Sigma philosophy includes a component of financial accountability, the Six Sigma team must estimate potential financial benefits and costs of each of the projects and develop a prioritized plan for implementation of the Six Sigma Student Success (S⁴) Program. Furthermore, since the Six Sigma philosophy emphasizes continuous monitoring and measurement, new needs may surface during project implementation, and other projects may be initiated.

As a case in point, two years ago, the university administration appointed a series of committees whose charge was to analyze a potential problem area (housing, registration, community involvement, financial aid, etc) and develop recommendations for implementation of solutions. The committees met in the summer and the fall. Reports from each committee were presented at a retreat at the end of the fall term. Many excellent ideas surfaced. Due to resource

limitations, only a few were implemented. It is significant, however, that the administration gave great visibility to the student success initiatives by appointing a half-time associate vice president for student success. In Six Sigma terms, this individual would be a Project Champion. A recent report indicates the preliminary initiatives have helped to improve student performance (Davis, personal communication, January 2004). Recently, however, it was announced that the university intends to commit substantial internal resources (primarily faculty and staff time) to one specific project initiated last year (learning communities). According to Six Sigma philosophy, selection, implementation, and continuation of projects is largely dependent on the overall needs of the institution, not individual departments. Thus, plans in one department may need to be adjusted to meet the needs of other departments.

The Six Sigma philosophy, in theory, makes project selection and continuation a function of potential financial return to the company. Politically correct projects should not be selected when other projects provide the potential for a better return. In reality, both in industry and academia, the life of a project is dependent on resources that can be provided or withdrawn for a variety of reasons. Built into the Six Sigma structure is recognition of the need for a strong Project Champion. The Project Champion, hopefully, is one who can continue to provide the necessary resources and maintains an awareness of the overall direction in which the institution is heading. Above all, those involved in Six Sigma projects must frequently communicate the benefits of the project they are working on. It is true that a good Six Sigma project may be eliminated due to the larger needs of the institution; however accurate records and frequent communication with upper management will help to preclude the discontinuation of a good Six Sigma project. Furthermore, in academia, the Project Champion is very likely to be an external funding agency. In our case, Project 2 was recently funded by the Engineering Information Foundation and is currently underway (Burtner and Backer, 2004).

Conclusion

The Six Sigma philosophy that has produced such good results for industrial concerns can be modified slightly and applied to academia. As in industry, the emphasis must be on the customers' needs. For our Student Success Initiative, we have defined the student as the most important customer. However, as in industry, we recognize the need to justify projects through data collection, communication and potential financial reward to the institution. Although some faculty are resistant to promoting projects because of potential financial benefit to the institution, many faculty recognize that we no longer live in an ivory tower in which projects and programs are implemented without regard to cost. Above all, good Six Sigma projects can provide university administrators with the data they need to make effective changes in programming and policy.

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