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Lawrence O. Jenicke, Anil Kumar, Monica C. Holmes

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A framework for applying six sigma improvement methodology in an academic environment

Lawrence O. Jenicke, Anil Kumar and Monica C. Holmes
Central Michigan University, Mount Pleasant, Michigan, USA

Abstract

Purpose – The six sigma methodology has been successfully implemented in many organizations leading to tremendous quality improvements in products manufactured and services delivered. However, academic institutions have lagged other organizations in implementing six sigma. The purpose of this paper is to examine the challenges of implementing the methodology in academia and proposes a framework that serves as a guide for implementing six sigma in academic institutions.

Design/methodology/approach – Several unique aspects that differentiate an academic environment from a manufacturing setting for six sigma are identified. A three-tiered framework to organize the six sigma improvement methodology and related academic performance indicators into a hierarchy fitting academic institution governance levels is proposed. Examples of strategic objectives and performance indicators by levels of implementation for the DMAIC process are also provided.

Findings – The findings suggest that the unique structure of an academic institution make it an interesting candidate for implementing six sigma. The three-tiered framework for six sigma can be used by administrators, faculty, staff and students as an implementation guide.

Research limitations/implications – The paper shows that significant differences between the environments make implementation in many areas within an academic institution challenging. However, there are limitations to the application of six sigma in an academic organization. The six sigma methodology has been more thoroughly developed and refined in manufacturing environments than in service systems such as in a university.

Practical implications – This paper helps to stimulate thinking about the application of a proven quality management methodology to academic settings where structured formal improvement programs such as six sigma are not commonly found.

Originality/value – The value of this paper is to provide a three-tiered hierarchical structure for applying six sigma in academic organizations.

Keywords Six sigma, Quality management, Strategic objectives, Quality improvement, Educational institutions

Paper type Research paper

1. Introduction

As customers continue to demand better quality products (services), companies have used various approaches to meet this need. Six sigma improvement methodology is one of the approaches that has been successfully used by companies in the US and other parts of the world to improve quality of products manufactured or services delivered. The name of the methodology, six sigma, denotes that any process should produce just 3.4 defects per million opportunities. In other words the goal is to make a process defect free. It must be clarified here that processes apply to both manufacturing and/or services.

Success stories of six sigma implementation and subsequent improvements in processes can be found in both academic journals and trade publications. The focus of these publications has however been on industrial (manufacturing and services)
processes. Not much has been written on implementing six sigma in an academic environment. While one can argue that academia is part of the service industry, we believe that there are characteristics that are unique to the academic world making it an interesting application area for the six sigma methodology.

Successful implementation of any methodology in an organization requires commitment from top management and employees. Top management becomes the champion for the methodology committing necessary resources needed to institutionalize the methodology. Employees on their part make sure that they study, use and appreciate the methodology to ensure successful implementation. This can be achieved by attending training courses conducted by the organization, self-study, enrolling in external (certification) courses or a combination of the above. Academic institutions are slightly different from business organizations. Similar to a business organization, top management in a university uses the vision and mission statements as tools to provide direction for the university. Individual constituents in a university, its academic colleges, departments and administrative units, often follow the principle of academic freedom that makes implementation of any campus wide initiative challenging. In this paper we identify challenges of applying six sigma in an academic setting and then propose a comprehensive framework for implementing six sigma in academic institutions.

The paper is organized as follows. In the next section we review the literature on six sigma in academia and identify the gaps in the research. In section three we identify and discuss the challenges of implementing six sigma in academic institutions. We propose a framework for implementing six sigma in academia in section four based on the challenges identified in the previous section. The paper ends with conclusions based on our research.

2. Literature review

Although various scholars have written on six sigma in academic institutions, the studies have a very narrow focus. While some studies focus on implementing six sigma to assist university administrators with decision-making on issues such as retaining students in academic programs based on extensive data analysis, others focus on integrating the six sigma methodology in an academic program (engineering, statistics, etc.), school or college. In the following paragraphs we discuss some of the key studies and their findings.

Several authors examine the role of six sigma to support decision-making in science and engineering programs at two different universities (Burtner, 2004; Hargrove and Burge, 2002). Burtner (2004) recommends using the six sigma methodology at the Mercer University School of Engineering to “provide university administrators with the data they need to make effective changes in programming and policy.” Four projects were identified as potential six sigma projects at Mercer University School of Engineering and these projects address issues ranging from retention and success of students in mathematics classes, reduction in the amount of time taken by students to graduate from an engineering program, and success stories of women as engineering students. A pilot study was conducted to “assess, evaluate, and monitor variation in student’s performance in the curricula and recommend methods for improvement” (Hargrove and Burge, 2002). The focus was on performance of minority and under-represented students in science and engineering programs. The six sigma methodology was used and preliminary results identified three factors: “need for
increased financial aid, development of faculty and an improvement in the instruction quality as being critical for success” that are critical to “retain the students currently enrolled, increase graduation rates, and the result is a more efficient process of producing well-qualified engineers to meet the technological needs of our nation.”

Several scholars have discussed integrating six sigma in educational programs. Mitra (2004) discusses the importance of incorporating six sigma concepts in statistical education including course contact and curriculum design. He emphasizes that six sigma education include the foundations and theoretical basis of the technique to foster statistical thinking rather than focusing on the ability to use a given tool. The success of TQM and six sigma programs in the private sector provides impetus for corporations to request (and provide grants) to include these programs in university environments (Wendt, 1994). Many of the tools supporting the six sigma methodology are not being taught in industrial and manufacturing management programs (Goffnett, 2004). His observation is based on a sample of industrial and manufacturing management programs listed in the National Association of Industrial Technology (NAIT) 2003 Baccalaureate Program Directory. Goffnett (2004) emphasizes that being six sigma fluent will help students to become employees that add “value to an organization.”

A few studies highlight the difficulties of implementing six sigma in a university environment. A list of unique challenges of implementing six sigma in a university environment was generated although the authors did not discuss the challenges (Holmes et al., 2005). The challenges include the difficulty in defining the customer for a university, the nature of the product, and the difficulty of measuring quality and reward systems for employees (Holmes et al., 2005). Hoerl and Bryce (2004) discuss the current status of six sigma in universities as well as its potential influence in academic environments. As a proven success in many business organizations, it is largely under applied in university settings. Applying six sigma in a university is difficult due to the intangible nature of an educational product, the diversity of departmental/individual goals and viewpoints, and the administrative focus on seeking funding for the university’s programs (Hoerl and Bryce, 2004). The best application areas may be in non-academic support areas. An earlier study pointed out several reasons for the difficulty of applying TQM in academia (Bolton, 1995). The reasons stated were unclear customer definition, lack of measurements of quality, emphasis on individual rather than group achievement, imposing uniformity, opposition to teamwork and resistance to change.

Though much has been written about six sigma in an academic institution, there is no study that identifies critical factors for implementing six sigma in an organized and coordinated manner across an academic institution. This study focuses on identifying these critical factors for implementing six sigma enterprise wide in an academic institution. The factors are used to propose a comprehensive framework that will guide academic institutions planning to implement six sigma.

3. The challenge of applying six sigma in an academic setting
The application of six sigma methodology to a university environment presents some unique challenges not found in a manufacturing setting. Quality management and improvement techniques including six sigma have been more thoroughly developed and refined in manufacturing environments than service systems (Gowen and Tallon, 1999). Applications of six sigma at Motorola, General Electric and Allied Signal have
yielded well-documented improvements to products and profits. Universities, which are predominantly services, are another story. The nature of the product, definition of customers, measurements of quality and employee reward systems differ significantly from those of manufacturing. In addition, difficulty of obtaining and analyzing data as well as a greater influence of uncontrollable factors complicate the picture. Building an organization-wide commitment in an academic system that values scientific and creative experimentation to a process which fosters efficiency-based thinking will be challenging.

**Definition of the product/customer**

Students may be viewed as both the product and the customer. As participants in the educational process they may be viewed as a product in process, a completed product (graduate), a customer for campus facilities and a customer for course material (Brewer et al., 2002). The student’s employer may also be viewed as the customer as can the parents/family, the community and society in general. Six sigma focuses on the customer by listening to the voice of the customer and then making improvements to the product (Douglas and Erwin, 2000). Will students, educators and employers agree on what skills and knowledge should be covered in the classroom? In academia, questions of who is the customer (or product) and assessing what the customer wants in a product make applying six sigma to the educational process much more difficult.

**Measurements of quality**

Measurements of quality are also much more difficult in an educational setting. The intangible nature of the educational process and product makes measurement vastly different from measuring the output of a manufacturing process where physical properties and well-established measurement procedures exist (Does et al., 2002). What each student receives from an education experience is often differentiated and not homogeneous. Students interact with the educational process and often become co-producers of their own learning, which adds to the uniqueness of what is learned (Chambers and Fernandez, 2004). Learning is obviously measured in academic settings through examinations and evaluation of assignments. Can these measurements be used as an indicator of educational quality? six sigma emphasizes a reduction in variability, which reduces defects and raises quality. Reduction in variation of classroom delivery and student performance outcomes may not be linked to an increase in the quality of education.

**Different reward systems**

Reward systems in business organizations, which have successfully implemented six sigma programs tie a portion of management/employee compensation to the success of the program (Goodman and Theuerkauf, 2005). One of the key components of the six sigma program at Motorola University (the education and training division at Motorola) is goal-directed incentives for managers and employees (Erwin and Douglas, 2000). Projects are undertaken with quantitative and measurable goals that are used as metrics for assessing the projects success and benefit to the organization. The reward system for the faculty at academic institutions emphasizes compensation for publishing, improving teaching and service activities. Pressure on faculty to excel in these areas is an individual focus on improvement, not an organizational focus. The
goals are to increase measures in these areas rather than reduce variation in faculty output.

Data and analysis difficulties
In a manufacturing setting, where physical properties are often measured, data collection systems are often in place or readily installed and measurement procedures are straightforward. Data quality is often high. Academic settings may not have systems in place to assess performance in some areas. Unlike manufacturing, academic processes have often not been subjected to a detailed analysis of their operations (Gowen and Tallon, 1999). Manufacturing operations often conduct formal studies of their inputs, transformation operations and outputs. These studies are used to design control systems for inputs and processes to achieve desired outputs. What is to be improved and measures of improvement in an academic environment are often unclear which makes the development of measurement and data collection systems difficult.

The use of analysis tools such as flow charts, cause-and-effect diagrams, Pareto analysis, histograms, scatter diagrams and run charts to analyze processes in manufacturing is common. Although these tools are easy to apply, their use in academic environments is not widespread. The application of six sigma in academia will require a prerequisite familiarity with and acceptance of these basic tools. In non-manufacturing environments, specifications are often one-sided and target levels are sought (Does et al., 2002). For example, minimum student retention percentages or percentage of faculty with PhDs could be goals for an academic unit but upper limits (except 100 percent) would be unusual. A nominal value for a target and reducing variation about the nominal would not be appropriate. The use of statistical process control chart and formal design of experiments to reduce variation in such areas would be less applicable.

Influence of uncontrollable factors
In an academic environment, many influences are often beyond the control of the academic system and difficult or impossible to quantify. For example, student success may be a function of personal motivation, psychological factors, sociological effects and family pressures. Factors such as these may have a strong influence on a desired or undesired outcome but are very difficult to control or measure. In contrast, manufacturing systems have factors that are controllable such as machine settings or uncontrollable factors or noise that can be quantified such as probability distribution of a machine output (Does et al., 2002). The presence of more non-quantifiable and uncontrollable factors in academic settings makes it more difficult to apply six sigma improvement methodology.

The preceding discussion has indicated some of the characteristics of academic environments that are different from manufacturing environments where six sigma has traditionally been applied. These present unique challenges to the application of the technique in academic institutions, which are generally not found in manufacturing environments. In the next section we propose a framework for the implementation of six sigma in academic institutions that can help to overcome some of these challenges.

4. Framework for Implementing six sigma
This is not to say that six sigma cannot be applied to improve the educational process. Academic institutions measure their effectiveness and quality through numbers of
freshman applications, student retention rates, incoming transfers, job placement rates and starting salaries etc. Revenues generated through fundraising activities with alumni as well as activities involving alumni provide measures of institutional support. Faculty activities can also be assessed. Aggregate as well as individual measures of participation in faculty development activities, number of publications in journals, ranking of journal publications, and presentations at local, regional, national and international conferences provide measures of professional engagement and growth. Many of these areas will be difficult to improve but some measurements exist and it can be a start for six sigma.

A key factor in applying the six sigma methodology to academic institutions is to identify performance indicators that are the best measures of organizational success. Many measures exist and determining the best ones to use depends upon where you are in the organization. A measure of performance success important to the president of the institution may not appear be relevant to a department chairperson or faculty member. We propose a hierarchical approach to implementing six sigma in an academic environment that is shown in Table I.

This three-tiered framework organizes the six sigma improvement methodology and related performance indicators into a hierarchy fitting institutional governance levels. At each level in Table I the six sigma improvement model of DMAIC (Define, Measure, Analyze, Improve and Control) is applied. Examples of performance indicators are also shown for each level. Some of these measures of success maybe found at more than one level in the hierarchy. For example, ACT scores maybe important for the university as a whole as well as an individual department major.

The hierarchical approach to applying six sigma requires coordination between and across the levels to ensure that improvement efforts benefit the entire organization. Otherwise implementing an improvement in one area may prove detrimental to another area. Different sub groups of any organization often have differing objectives and measures of success that may conflict with another. Using performance indicators that are readily available or easily measured without considering the organization as a whole may also yield poor results. The six sigma approach applies the DMAIC improvement process to achieve desired levels of performance and it is critical that what is to be improved be selected in concert with overall organizational goals and strategic objectives.

The hierarchical approach can be applied to the selection of performance indicators appropriate to each level and consistent with the institution’s strategic objectives. Table II presents some examples of long-term strategies objectives for an academic institution and a hierarchical categorization of performance indicators for the DMAIC process. The long term strategic objectives in the table reflect the ability of the institution to market itself through its reputation, maintain financial resources, recruit and retain high quality students and maintain professionally qualified faculty. The performance indicators at the top are the most general in nature covering the longest time horizon with the indicators at the bottom being more specific and shorter term in nature. In general, the time required for the six sigma improvement process will vary by institutional level.

Six sigma can be applied in an academic setting but the implementation of successful, organization-wide programs such as those found in manufacturing settings will be difficult. Section three of this paper presented some of the challenges involved in its application to academic environments. Portions of the six sigma methodology can certainly be used to improve many processes within an academic institution at any level in the organizational structure. The entire six sigma methodology does not have to be used
Levels of implementation | Six Sigma methodology | Performance indicators
--- | --- | ---
Tier 1: university level | Define | State funding  
New buildings  
ACT scores  
Benchmarks with other universities
Tier 2: college and school level | Measure  
Analyze | Financial resources  
Employer contacts  
Alumni contacts  
New hires  
Faculty publications  
Private funding  
Assessment measures (EBI, etc.)  
College placement rates  
Percent of professionally qualified faculty  
Percent academically qualified faculty
TIER 3: department and major level | Improve  
Control | Department funding  
Growth of majors  
New programs  
New courses  
Student opinion survey scores  
Committee achievements  
Advisory boards  
Faculty growth (awards, training, etc.)  
Percent faculty involved with student organizations  
Curriculum development  
Increased use of technology  
Better use of technology  
Percent of students involved with student organizations  
Placement rates by major  
Course development

Table I.  
A three-tier comprehensive framework for implementing Six Sigma methodology in academia

Note: In this table, departmental measures are not repeated at the college’s level and college measures are not repeated at the university’s level

(Goodman and Theuerkauf, 2005). Projects can be identified, goals established and measurements established for areas leading to incremental improvements. Initially, the best areas for applying six sigma in universities may be in non-academic support areas (Gross, 2001). Projects can be found in the support area of information system, facilities management, purchasing, financial activities, human resources, registration procedures, course scheduling, student housing and campus security. Successful applications of six sigma in these areas can provide familiarity with the process and lay the foundation for applying it directly to academic areas.

The advantage of focusing the methodology on non-academic functions, centers on the more tangible processes that are similar to many business processes, which have benefited from six sigma efforts. A more distinct view of who is the customer and listening to the voice of the customer is possible in these areas. For example, a student (customer) wants a class at a particular time – registration requests and class
### Table II.
Examples of strategic objectives and performance indicators by levels of implementation for the DMAIC process

<table>
<thead>
<tr>
<th>Implementation level</th>
<th>University</th>
<th>College/school</th>
<th>Department/major</th>
<th>Institution</th>
<th>Fiscal position</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Institutional reputation</strong></td>
<td>Overall alumni satisfaction</td>
<td>Alumni contacts with college/school</td>
<td>Number of student professional organizations</td>
<td>Overall quality of incoming freshman</td>
<td>Alumni donations to college/school. Endowed professorships available</td>
</tr>
<tr>
<td></td>
<td>Overall employer satisfaction</td>
<td>Employer contacts with college/school</td>
<td>Involvement of students in professional organization activities</td>
<td>Overall quality of incoming freshman</td>
<td>University funding for college/school</td>
</tr>
<tr>
<td></td>
<td>Placement of graduates</td>
<td>Number of internship programs</td>
<td>Number of student internships</td>
<td>Average ACT scores for incoming freshman</td>
<td>New buildings/facilities available</td>
</tr>
<tr>
<td></td>
<td>Overall employee satisfaction</td>
<td>Overall student placement rates for college/school</td>
<td>Faculty consulting activities</td>
<td>Average GPA for incoming freshman</td>
<td>Funds available for department/major</td>
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<tr>
<td></td>
<td><strong>Fiscal position</strong></td>
<td></td>
<td>Number of student preferences for majors</td>
<td>Student retention rates for college/school</td>
<td>Department operating funds</td>
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<tr>
<td></td>
<td>Annual state funds available</td>
<td></td>
<td>Student success in professional certifications</td>
<td>Overall student satisfaction</td>
<td>Employer donations to department/school</td>
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<tr>
<td></td>
<td>Annual donor funds available</td>
<td></td>
<td>Student placement rate by major</td>
<td>Assessment measures (EBI, internal measures)</td>
<td>Endowed professorships for majors</td>
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<tr>
<td></td>
<td>Costs per credit hour</td>
<td></td>
<td>Percent of faculty involved in student activities</td>
<td>Admissions standards for majors</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Student quality</strong></td>
<td></td>
<td>Percent of faculty involved with student organizations</td>
<td>Student retention rates for majors</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Overall quality of incoming freshman</td>
<td></td>
<td></td>
<td>GPA by majors</td>
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<td></td>
<td>Overall student retention rates</td>
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<td></td>
<td>Student performances on internships</td>
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<td></td>
<td>Average ACT scores for incoming freshman</td>
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<td></td>
<td>Student performances on internships</td>
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availability data are available. A faculty member (customer) processes a travel requisition – data are available to measure reimbursement amounts and processing times. An academic department (customer) requests a new copier – purchase price and delivery time data are available from purchasing records.

Measurements of quality, which are essential to improvements, are also easier to obtain in support areas. Budget performance reporting for non-academic as well as academic departments provide data on department activities (volume) as well as dollars spent. Six sigma improvement endeavors often require special measurements to help identify problems rather than symptoms of problems. Data collection systems that quantify errors or defects must be developed to support the analysis in six sigma projects (Gross, 2001). These will be easier to establish where existing systems already exist.

Employees in non-academic support areas have compensation and reward systems that are similar to their industrial counterparts. Workers are evaluated and rewarded for improving processes and output as well as learning job skills that increase their value to the organization. This is in contrast to faculty who are pressured to improve in areas where assessment is inherently difficult – teaching effectiveness, research and service activities. Setting goals that are measurable and quantifiable to assess six sigma process improvements and rewards to recognize employees (i.e. black belts) for achievements will be easier where measurements can be established.

5. Conclusion
In this paper we have demonstrated that although there are not too many examples of six sigma implementation in academia, it is possible to use this methodology for improvement. We initially identified challenges to implementing six sigma in academia and then propose a framework that can be used as a manual to implement six sigma in an academic institution. This framework will be useful for all stakeholders (administrators, faculty, staff and students) that are a part of the academic environment. The framework provides transparency to the stakeholders in terms of what is the objective behind implementing the methodology.

It must be mentioned here that the role of top management is very critical if six sigma is to be implemented successfully. Just like in industry, top management has to step up and be the champion of the six sigma implementation in an academic setting. Top managers must clearly communicate the rationale behind the implementation, the expectations from stakeholders and anticipated results. Openness and involvement of the stakeholders at every stage of the process will ensure success. Furthermore, while time constraints may make it difficult for a university president to undergo six sigma training, college and departmental heads can set an example by participating in six sigma training. This will encourage staff to participate in training.

References


**About the authors**

Lawrence O. Jenicke is a professor in the Management Department, College of Business Administration, Central Michigan University, Mount Pleasant, Michigan, USA. Lawrence O. Jenicke is the corresponding author and can be contacted at: jenic1lo@cmich.edu

Anil Kumar is an associate professor in the Business Information Systems Department, College of Business Administration, Central Michigan University, Mount Pleasant, Michigan, USA.

Monica C. Holmes is Associate Dean and professor at the College of Business Administration, Central Michigan University, Mount Pleasant, Michigan, USA.

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