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Full Length Research Paper

Utilising six sigma for improving pass percentage of students: A technical institute case study

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Service sector accounts for a substantial share in Indian economy and among the service industries, education sector is emerging as a major commercial activity in the nation. Globalization, growing competition among institutions, emergence of new technologies, changing socio-economic profiles of nations and knowledge driven economies have created a scenario where quality in education is beginning to occupy the centre stage. Now the quality is no more a desirable strategy – it has become a survival strategy. In such a scenario, 'Technical Education Institutions' require an innovative supporting tool, which helps in improving the quality of education system. In industry, a company may look at defects in its final manufactured products, whereas, in engineering education, a defect relates to falling pass percentage among students. In industry, a company may look at defects in its final manufactured products, but in engineering education, these defects are related to falling pass percentage among students or capabilities of the students. This paper reviews the implications of applying Six Sigma methodology over a technical institute to increase the passing rate of students. It was found that application of Six Sigma project recommendation increased the sigma level of the technical institute to 4.17 from 2.28 and significantly resulted in increasing the passing rate of students. This article provides documented evidence of Six Sigma implementation in technical education in India and will yield a great value to academics, consultants, researchers and practitioners of Six Sigma.

Key words: Six sigma, DPMO, DMAIC, technical institute.

INTRODUCTION

Service sector has experienced significant growth over the past several decades and it accounts for a substantial share in Indian economy. Even in under developed countries, the service sector still accounts for a substantial part of their economies. The service industries have not only grown in size, but along the way, these have absorbed all the jobs rejected by traditional industries such as agriculture, mining and manufacturing. For instance, in the mid-1990s, the service industries employed nearly 80% of the workforce in the USA (Su et al., 2006). According to Pande et al. (2002), most service organizations operate at sigma quality levels of 1.5 - 3.0 that is, a defect rate between 455000 and 66800). This is not surprising, considering the fact that for decades, (service sectors have been neglected in the context of quality improvement efforts.

Recently, Six Sigma as an improvement approach has been seriously attracting the attention of service industry. The popularity of Six Sigma in service organizations is growing exponentially, especially in banks, hospitals, financial services, airline industry and utility services. The quality of education is going to be an issue of foremost importance in the future in India and is an urgent need of the hour. In this age of globalization, the societal attitudes towards education have gone through radical changes. Today, higher education has become a commercial enterprise and is being treated as a marketable commodity. Many countries and universities throughout the

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world are preparing for marketing their education products and services in India. Day by day the competition from foreign universities is mounting up. So, education sector has been selected for this case study representing the service sector. Six Sigma is a set of methodologies used in business to achieve extremely low failure rates in any process. Similarly, it can be used to achieve excellence in the field of education by improving the overall performance of the students. Education being a service industry where clients are the students and the quality of learning they achieve is the service. It can be presumed that student is the 'product', which an education institute 'sells' to the future employer.

Education has multiplying effects on all facets of development in a society and among various educational resources; engineering education holds the key to economic viability of a nation (Ho and Wearn, 1995). All over the world, engineering education has been intensified in the universities during the past four decades. On this front, India has also formally recognized the importance of higher education on science and technology and committed itself to the development of science and technology manpower by providing full policy support and substantial public funds to create one of the world's largest network systems of higher education system (Naik, 2004). In engineering education sector during last few years, the number of self financed colleges has increased at an alarming rate, thereby causing acute shortage of faculty. Most of these colleges have been established with commercial motives and less emphasis is being given to quality of the education being imparted. To monitor the quality of technical education, the process of accreditation has been introduced. NBA (National board of accreditation) under AICTE (All India council of technical education) has been constituted to do accreditation process. But NBA concentrates more on the system development and overlooks the aspect of customer satisfaction as a means of evaluating the quality level (Ahuja, 2004). In engineering education sector, there are many stakeholders like students, managements, government, industries, parents etc. and this makes the system very complex. Since students are the primary stakeholders in the system and their primary objective is passing the final examinations to vie for gainful employment, so, passing rate of students is being accepted as a parameter to evaluate these privately managed engineering institutions. Raised expectations by academicians, educationists, policy planners and the society have threatened the sustainability of these institutions in the present competitive life. For understanding the gravity of the problem, a 'Chain of Causation' structure showing the vicious cycle of problems in the technical institutes has been prepared. On the basis of this structure, the Six Sigma methodology can be easily linked to the passing rate of the students or more precisely the overall quality of education being imparted in any technical institute. However, a moot question arises; is passing rate an important factor that reflects the quality of a technical institute? The answer is – yes; it reflects the quality of any technical institute significantly, though there are many other factors also. But by increasing the passing rate of the students, these factors can easily be dealt with. Figure 1 shows the chain of causation diagram showing various factors that directly or indirectly affect the quality standards of a technical institute.

In this scenario, technical education institutions require an innovative supporting tool, which can help in improving the quality of education system. People in the industries, from manufacturing to service, are witnessing the growth of a strategic continuous improvement concept called Six Sigma. In industry, a company may look at defects in its final manufactured products, but in engineering education, defects can be related to loss of students. This study is the first initiative to implement Six Sigma DMAIC (Define, Measure, Analyze, Improvement and Control) methodology in a technical education institute to increase the passing rate of students.

Six sigma and its goals

Sigma is a Greek letter representing standard deviation or the amount of variation within a given process (McAdam and Lafferty, 2004). According to Harry and Schroeder (1999), Six Sigma is a powerful breakthrough business improvement strategy that enables companies to use simple and powerful statistical methods for achieving and sustaining operational excellence. It is a business strategy that allows companies to drastically improve their performance by designing and monitoring everyday business activities in ways that minimize waste and resources while increasing customer satisfaction. Park (2002) described that Six Sigma implies three things: Statistical measurement, management strategy and quality culture. It is a measure of how well a process is performing through statistical measurement of quality level. It is a new management strategy under leadership of the top management that creates quality innovation and total customer satisfaction. It is also a quality culture. It provides the way to do things right at the first time and to work smarter by using data information. It also provides an atmosphere to solve many CTQ (critical-to-quality) problems through team efforts. Statistical representation of Six Sigma describes quantitatively, how a process is performing. The goal of Six Sigma is to design processes that do what they are supposed to do with very high reliability, ultimately producing very consistent products and services (Coronado and Antony, 2002). The numerical goal of Six Sigma is reducing defects less than 3.4 parts per million (PPM) also known as 'Defects Per Million Opportunities' (DPMO), reducing cycle time and reducing costs dramatically, which impact the bottom line (Behara et al., 1995; Goh and Xie, 2004).

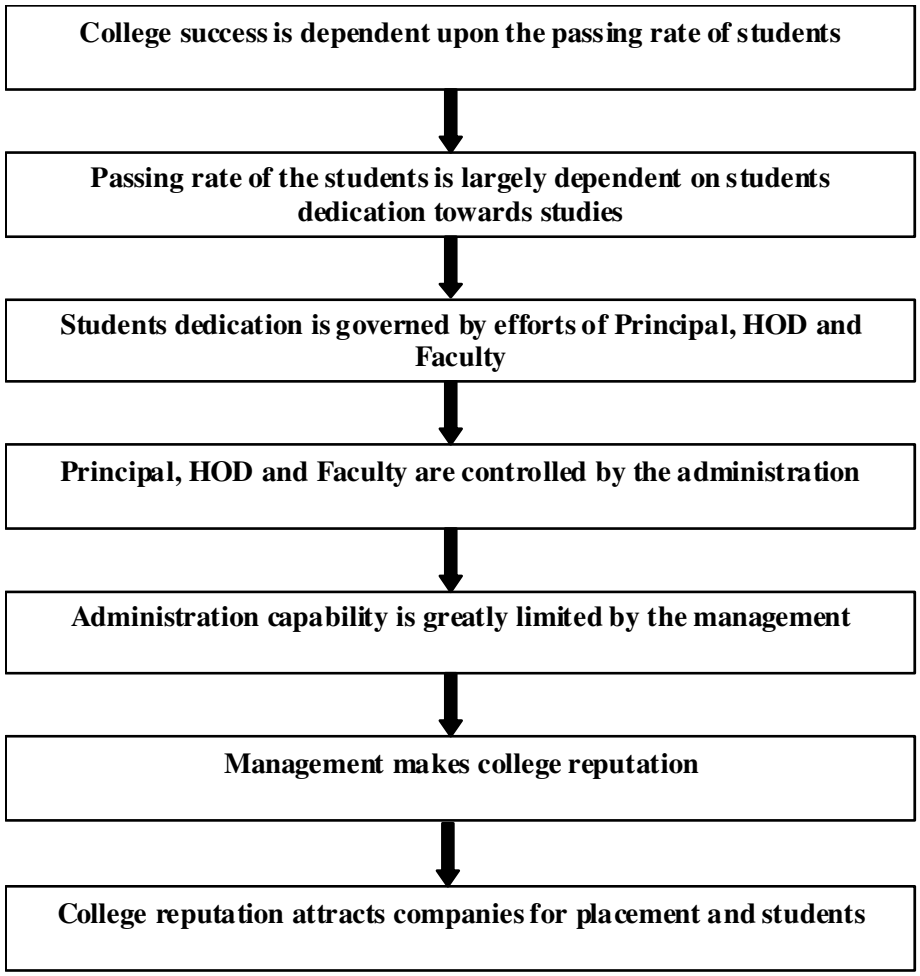

Figure 1. Chain of causation.

Six sigma professionals: From industry to institute

Six Sigma is not just about statistical tools and defect calculations, nor is it about having people work in teams. Teams alone cannot change corporate or educational structures. They must be part of an infrastructure designed to assist in the redesign of organizations, like scaffolding around a building being renovated. One way to understand this renovation structure is to review the role of people in the organization. For this purpose Six Sigma professionals in an organization came into existence. The first step towards the implementation of Six Sigma is to build a deployment platoon, trained with varying levels of proficiency in the art of Six Sigma. The measure of proficiency on the tools of Six Sigma is denoted by the colour of one's belts as in the karate (Martial arts). The deployment platoon of Six Sigma consists of Champions, Master Black Belts (MBB), Black Belts (BB) and Green Belts (GB). These professionals have a single goal in mind from the inception of concept of Six Sigma 'to achieve the level of Six Sigma in minimum time span' (Ingle, 2001). The comparison between the duties performed by various Six Sigma professionals in industries and in technical institutes is as shown in Table 1.

About the case study

India has developed a vast and rich network of about 4000 engineering institutes and nearly eighty percent of these institutions are being managed by private managements. In these institutions, the aspect of quality is mostly being overlooked, as profitability is emerging as the primary motto. So, in the presence of varying objectives and constraints, a new set of performance parameters is evolving at these privately managed institutes. Major performance parameters gaining acceptability are job placements, passing rate of students, extra curricular achievements etc. In this case study, problem formulation involves enhancing the institute rating by selecting and 'improving the passing

Table 1. Equivalence between six sigma professionals in industries and in institutes.

Six Sigma professionals in industries	Six Sigma professionals in institutes
Leadership group council	**Governing body**
1. Senior Managers – they plan and execute Six Sigma plan.	1. Members of Management/Management Committee
2. Their aim is to achieve Six Sigma in a planned way.	2. Proposes the Six Sigma plan to management
Project sponsors and Champions	**Principal/Head of institute**
1. A senior manager with an experience in Six Sigma projects.	1. Sets up a goal for improving project
2. Accountable to leadership council for success of projects	2. Finds resources for the team.
	3. Advocates for the team efforts in management
Six Sigma coach (Master black belt)	**Head of departments**
1. The Six Sigma coach provides expert advice to Six Sigma improvement teams.	1. Communicate with principal and management.
2. He acts as a mentor and a trainer.	2. Deals with resistance to implement Six Sigma.
	3. Help to resolve team and other conflicts
	4. Gathers and analyses data about team activities.
Team leader/Project leader (Black belts)	**Professor in charge**
1. The team leader accepts primary responsibility of result of Six Sigma project.	1. Reviews/revises/clarifies the project.
2. They are specified to one team only	2. Works with team members.
	3. Selects the project team members.
	4. Identifies and finds resources for team
	5. Documents final project results.
Team members (Green Belts)	**Student advisory committee**
The team members bring the brain and measure for collection and analysis of data needed to improve the process.	1. Carries out instructions for data collection and analysis
	2. Carries out assignments.
	3. Reviews the efforts of the team itself.
	4. Learns new data-driven ways to manage the operation
Process owner	**Process owner**
1. The process owner is normally the manager of a part of a particular function.	1. All faculty members and staff of the technical institute.
2. They receive solution created by an improvement team and become "owners" responsible for managing the improved process.	2. They are responsible for continuous improvement and maintenance of the same.

rate of students' as the key process for Six Sigma implementation. Loss of students has been taken as a measure of defects for the process. An initiative has been made to implement Six Sigma and analyze the results at Shri Krishan Institute of Engineering and Technology (SKIET), Kurukshetra (Haryana).

For the study, the passing rate data of various engineering colleges affiliated to Kurukshetra University, Kurukshetra (KUK), Haryana (India) was collected for the last nine years. After analyzing the collected data, it was found that the average passing rate of students at SKIET was very low (51.27%) and the institute was operating at a Z- bench sigma level of 2.17 with existing DPMO level of 15134.07, which was remarkably high. Hence, the main critical to quality (CTQ) measure selected for Six Sigma implementation is to improve the pass percentage of students in SKIET.

APPLICATION OF SIX SIGMA DMAIC METHODOLOGY IN ENGINEERING INSTITUTE

To solve any problem, the methodology adopted must cover all possible causes of problem. If the methodology of problem solving is not comprehensive enough, the solution obtained at completion will not be correct and problem will resurface sooner or later. A process flow chart is prepared to proceed in a sequential manner and to present a one shot picture of the entire methodology, as shown in Figure 2.

For successful implementation of the Six Sigma methodology in technical institutes, two main factors, that is, senior faculty and management of the college must have confidence in Six Sigma. For this reason, presentations of methodology and resulting expected benefits were made clear to management and senior faculty members. In this way, the necessary support for analysis of the problem and implementation of the recommendation was acquired. A Six Sigma Program Implementation Team (SSPIT) from different disciplines was formed (including the Principle, Head of Departments, Senior Faculty, and Senior Students from different disciplines) to facilitate application of Six Sigma to the problem. The team met regularly during the different stages of the project.

The five-step improvement cycle using Six Sigma organizations, DMAIC has been successfully implemented in an engineering college to increase the pass percentage of students as explained in the text.

Define

Defining the problem and defining what the customer requires (Kapur and Feng, 2005).

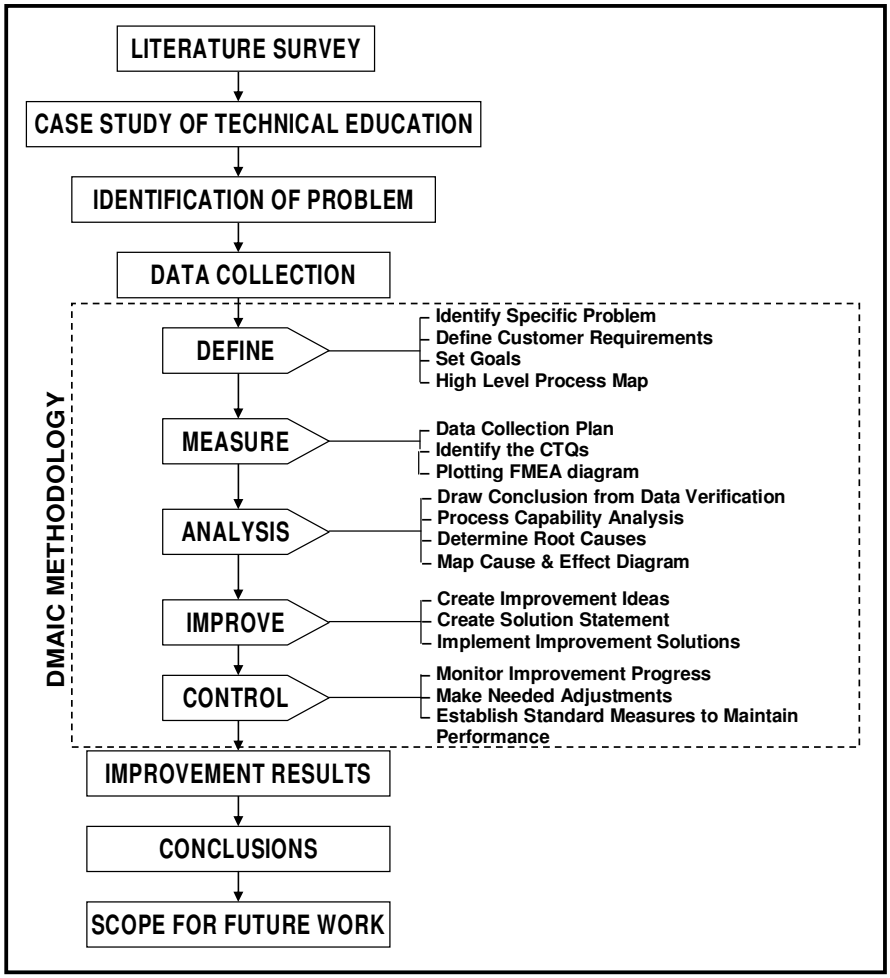

Figure 2. Flow diagram of methodology adopted.

In the define phase, a High Level Process Map- a Supplier, Input, Process, Output Customer (SIPOC) diagram, was drawn for passing rate of students as shown in Figure 3.

Measure

To study the problem of low passing rate of students, the data needs to be selected for such duration that all possible variations in passing rate are covered. For this, nine year data (eighteen semesters) of passing rate of students of various engineering colleges affiliated to KUK was collected. As the maximum passing rate is most desirable for an engineering college, so, for this problem, only LSL (Lower Specification Limit) of 43 and target value of 64.27 were specified on the maximum basis of lowest passing rate of the institutes selected and target value decided on the maximum basis of result among the data of all institutes.

Critical to quality (CTQs) characteristics of the process were identified and this phase helped in determining the factors that contributed to student attrition. Many engineering retention studies indicate factors like financial aid, faculty-student relations, curriculum, and academic services etc that influence the passing rate. Once the CTQs are identified, surveys and interviews can be used to measure their effects on passing rate.

A failure mode and effects analysis (FMEA) is a procedure for analysis of potential failure modes within a system for the classification by severity or determination of the failures' effect upon the system. It could be understood more clearly by plotting a FMEA diagram (as shown in Figure 4) where all the defects that occur are connected to the causes and effects to explain the relationship between the causes (factors that are responsible for low passing rate), failure mode (low passing rate) and failure effect (the dissatisfaction of the parents and the students).

Analysis

Data is analyzed and the causes of the problem are discovered using tools as explained.

Run chart

A run chart or trend chart was drawn from the passing rate data of the college in question. Purpose of this chart was to identify the special cause of variation measured over time (Tennant, 2001). It is used to provide the information on the non-random variation due to Form the result obtained using Minitab, P-values (Figure 5) for clustering (0.68649), trend (0.78406), oscillation (0.21594) and mixtures (0.31351) are more than significance level of 0.05, indicat-

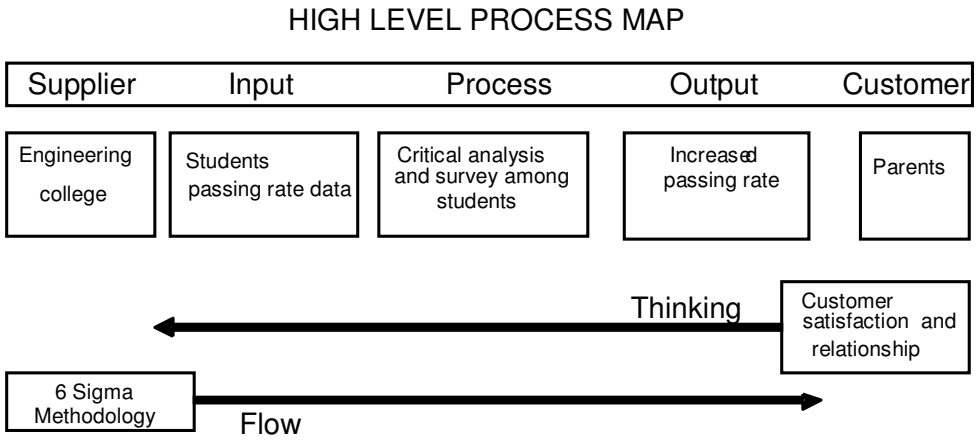

Figure 3. High level process map for low passing rate of students.

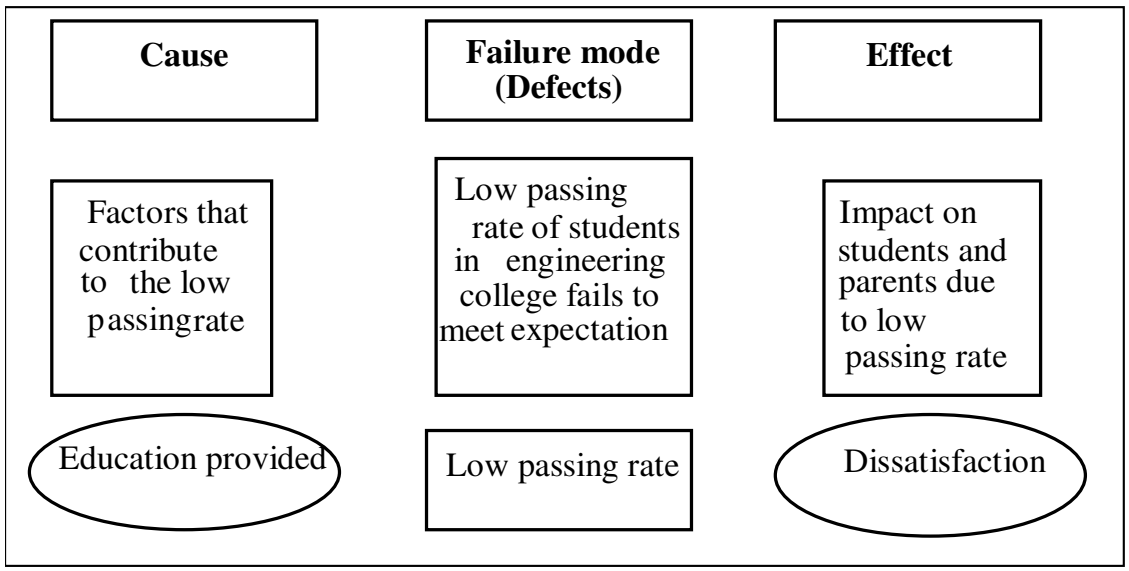

Figure 4. Failure mode and effect analysis (FMEA).

ing no special causes of variation in data.

Histogram

A histogram helps to display a large amount of data that is difficult to interpret and to identify the mean relative to customer specific requirement. By providing a visual summary of data, the histogram reveals whether the process is centered on a target value or the data meet specification.

The histogram in figure 6 clearly shows that the data was not centric and the mean is far beyond the target (0.64) value, which shows the problem of centering.

Process capability analysis

Process capability analysis was performed to find out the actual state of the process. Minitab was used to draw the process capability analysis curve for the passing rate of students from the engineering college as shown in Figure 7. From the result, the Z-bench sigma value of the SKIET was found to be 2.28 and the existing DPMO level of the college was found to be 11182.03, which is remarkably high (Figure 7). This shows that there is a need for drastic improvement in the present standards of quality of education in the institute.

Fish-bone diagram

Using the experiences of Principal, Head of department (HOD) of various branches, faculty members and views of senior students of the institute, a fish bone diagram was drawn (Figure 8) to find out the causes of low passing rate of students in the overall result of the college.The brainstorming points (Critical Systems) with their key critical factors (KCF's) in the fish bone diagram as follows:

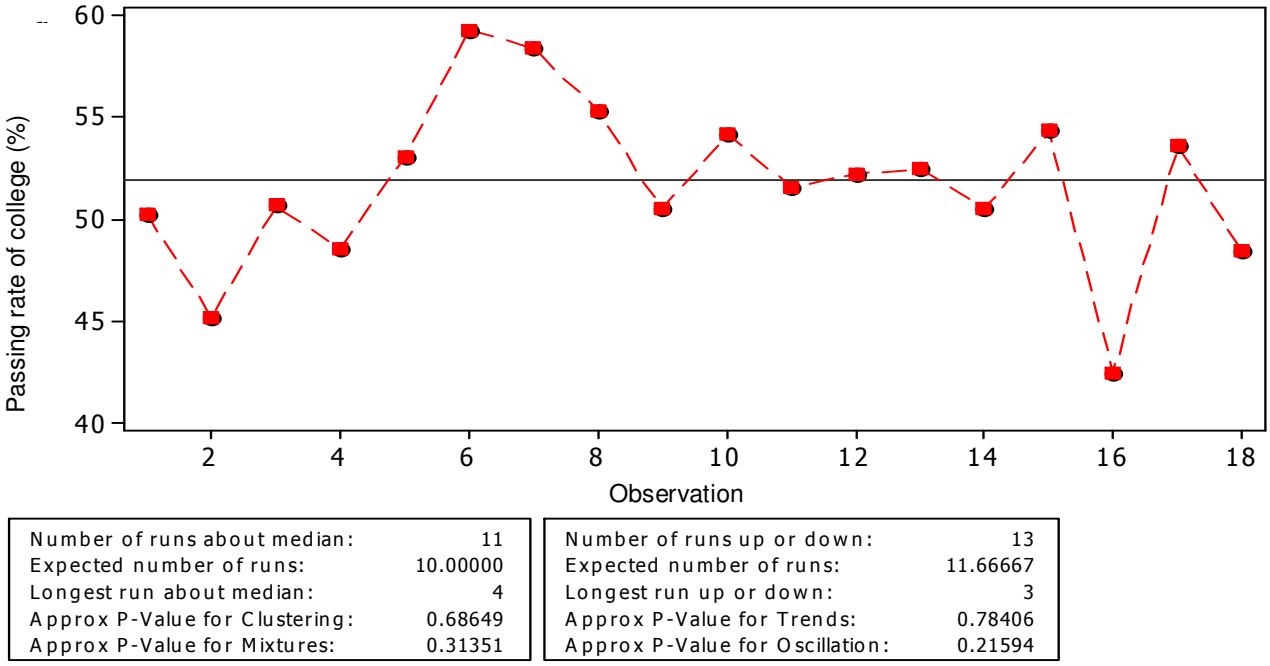

Figure 5. Run chart of passing rate of students before six sigma application.

Infrastructure: Campus building, Laboratories and equipments, Library, Computer and internet and Hostel Facility.

Faculty: Qualification, Experience of faculty, Level of Knowledge, Teacher student ratios, Teaching style, Degree of motivation by faculty and Parent's lecturer interaction.

Management: Amount of investment, Efficiency of administration, Scholarships, Provision of financial help for students of weaker class, Provision of adequate power to principal and faculty and Accreditation of college.

Student faculty relationship: Opportunity of informal interaction, Student perception of faculty, Counseling sessions for weak students, Coaching/extra classes (if required), Attitude of students and Feedback from students.

Examination pattern: Pattern of question papers, Pre-defined syllabuses, Adequate times between exams, Evaluation criteria, Transparency and Conducting mock examinations.

Administration: Effectiveness, Discipline and decorum, Placement cell with qualified TPO, Emphasis on industrial training, Feedback from alumni and Provision for qualified counselor.

Pareto chart

A Pareto chart was drawn, which shows components of the problem that have the biggest impact. The Pareto chart has been prepared on the basis of impact factors calculated by applying PO-P (Performance Objective-Productivity) approach (Vrat et al., 1998) on the results of the survey (Collective Opinion and Paired Comparison methods) conducted among the faculty and senior students of the college. It highlights the critical factors having the maximum impact on the passing rate of the students of the college as shown in Figure 9.

Improve

After a detailed analysis of the data in analysis phase, brain-storming sessions were carried out to suggest possible measures to cope up with problems faced by the selected institute. The optimal solution for improvement in passing rate of students is determined and confirmed in the improve phase. The gains from the improve phase are immediate and are corrective in nature. Specific problems identified during analysis were attended in improve phase. Important issues of management, faculty, infrastructure and administration were identified and action plans were prepared to tackle all such problems as shown in Table 2. In this phase, the improvement actions were carried out on the causes of low passing rate of students as mentioned in the analysis of the fish bone diagram.

Control

It is the final stage of Six Sigma implementation to hold the gains that have been obtained from the improve stage. Hence in this stage, the new process considerations are documented and frozen into systems so that the gains are permanent. All the possible related problems of the specific identified problem from the analysis phase were tackled in control phase as described in Table 2.

IMPROVEMENT RESULTS

After improvement, by analysing the next five semester result of the SKIET, it was found that application of project recommendation increased the sigma level of the SKIET to 4.17 with DPMO level of 15.05 (an improvement of 11166.98) and mean of the passing rate increased to 61.348 (an improvement of 9.641 mean)

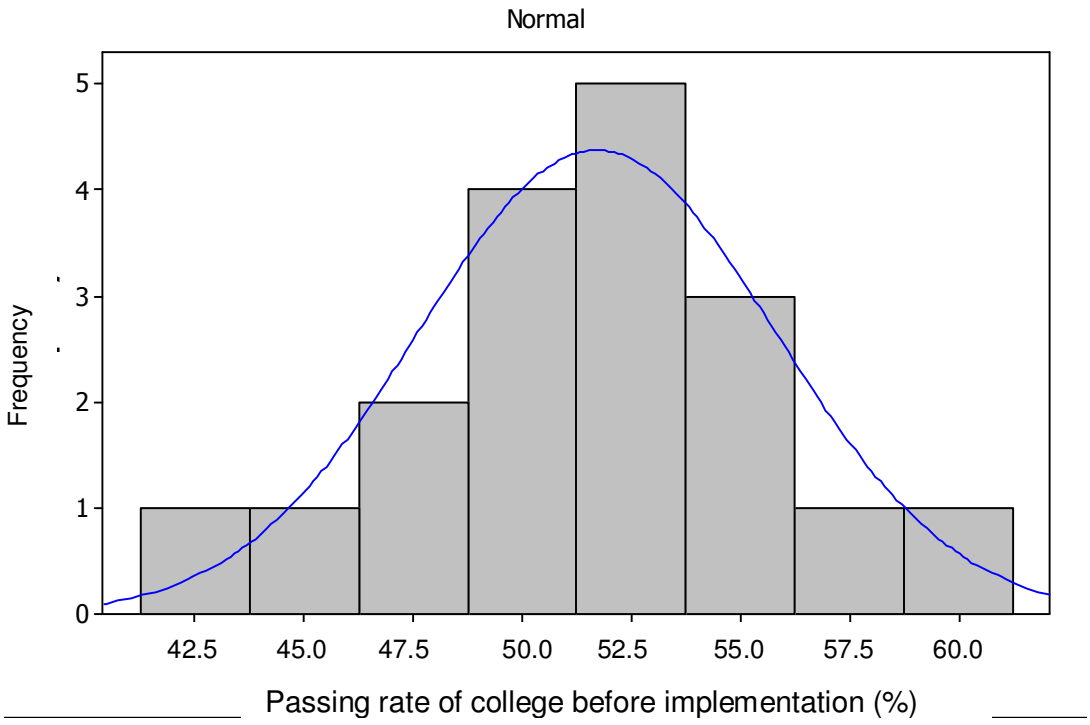

Figure 6. Histogram of passing rate of students before implementing DMAIC Methodology.

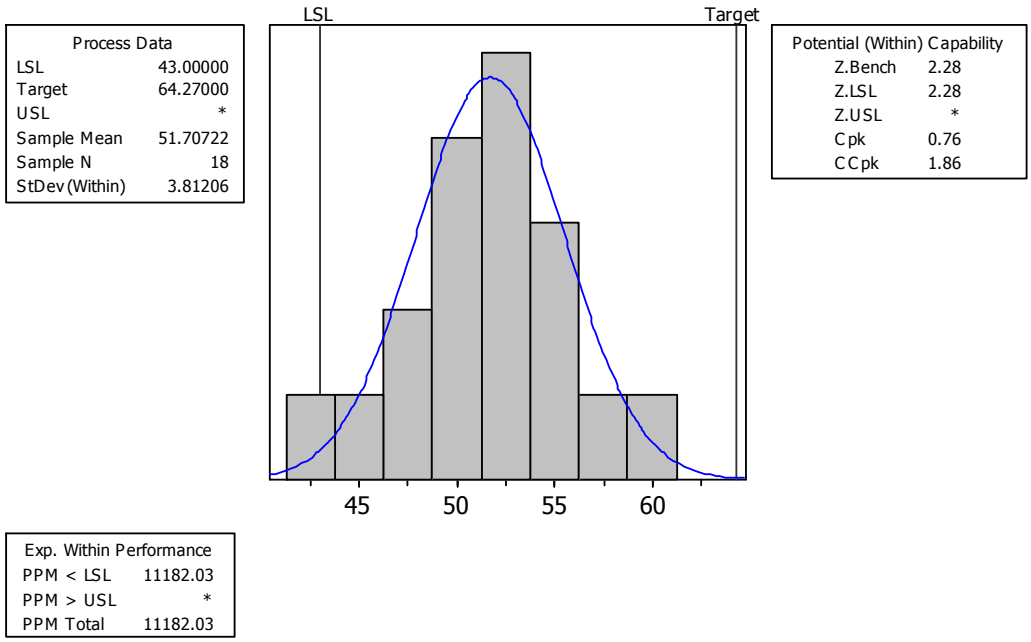

Figure 7. Process capability analysis of passing rate of students before implementing DMAIC methodology.

(Figure 10), which is substantial for an educational organization. A few more agreed recommendations are yet to be implemented and it is expected that this will further improve the sigma level.

Conclusion

Six Sigma has produced many positive results for many world class companies. An attempt has been made to

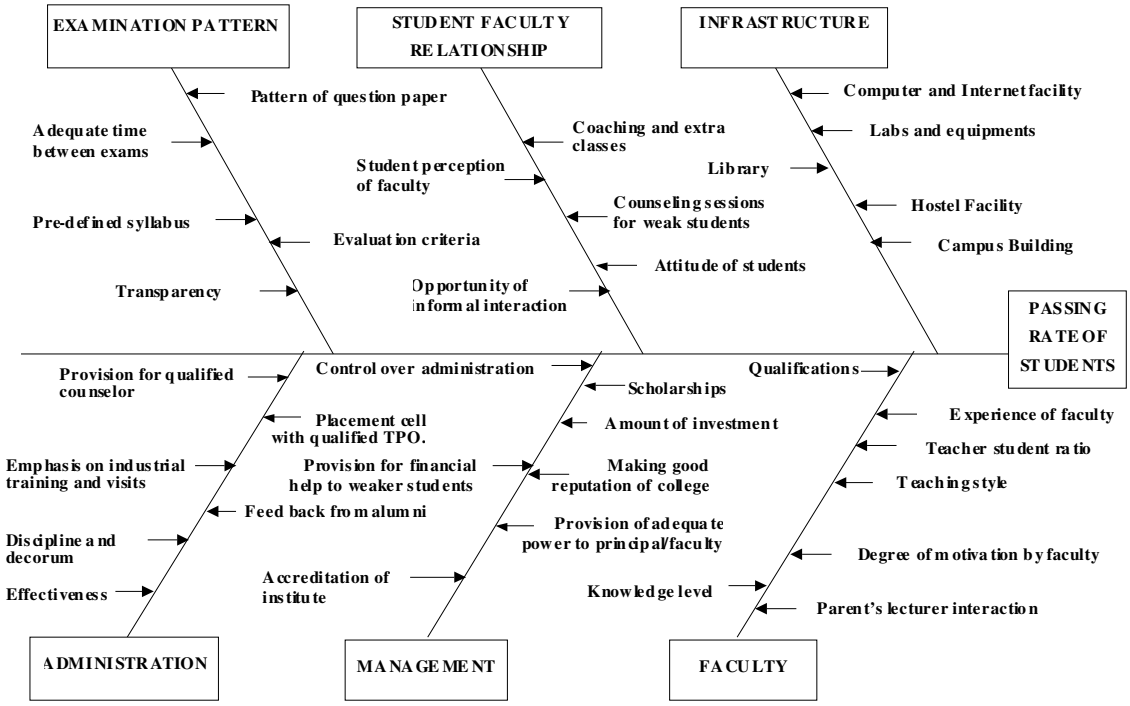

Figure 8. Fish Bone diagram.

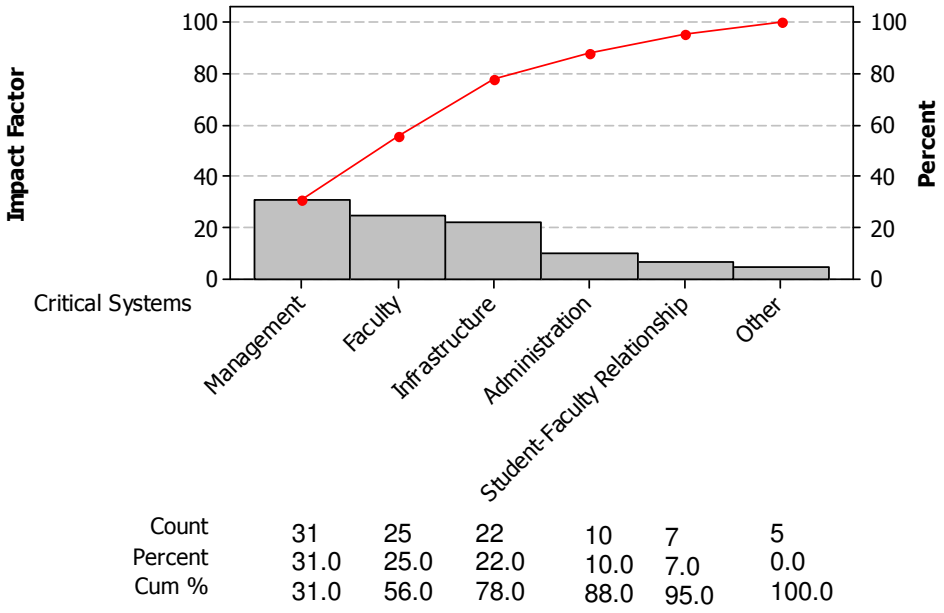

Figure 9. Pareto analysis of critical systems.

highlight a relationship between the applications of Six Sigma in corporations and in higher education. Six Sigma provides a philosophy to meet the diverse needs of highlight a relationship between the applications of Six Sigma in corporations and in higher education. Six Sigma provides a philosophy to meet the diverse needs of industry with improved customer satisfaction and similarly, in academics, an institute can also be experimented

Table 2. Action Plan (Improve and Control phase).

Critical system	Key critical factors	Recommendation proposed	Status
Infrastructure	a) Campus building	1. To hire architects and agencies for systematic planning of buildings.	Executed (Management agreed)
		2. Unplanned expansion to be curbed.	In Process
	b) Laboratories and equipments	1. Enough space to be provided for labs as per All India council of technical education (AICTE) norms.	Executed
		2. Laboratories to be fully equipped with all the required amenities.	Executed
	c) Library	1. To provide software for automation of library.	Software ordered
		2. Separate AC reading halls for staff and student.	Executed
		3. To subscribe new journals and books as per requirement of faculty and students.	Executed
	d) Computer and internet	Separate Internet labs to establish in all the departments.	Implemented
	e) Hostel facility	1. Extension of boys hostel, building new rooms	In process
		2. Construction of new girls' hostel and faculty quarters.	Constructed
		3. To provide coolers in all the rooms in hostels.	Implemented
Faculty	a) Qualification	Preference to be given to M. Tech (Master of Technology) and PhD candidates for new recruitments.	Implemented
	b) Experience of faculty	Recruits some retired faculty from reputed institutes.	Implemented
	c) Level of knowledge	Scheduling of FDP (Faculty development programme) in every six month.	Two--FDP conducted
	d) Teacher student ratio	To maintain fair ratio of teachers and students as per AICTE norms.	Implemented
	e) Teaching style	Provision for modern teaching aids like projectors.	Provided
	f) Degree of motivation by faculty	Constitution of career advancement cell for guidance and motivation of students.	Executed
	g) Parents lecturer interaction	1. Monthly Parents teacher's interactions to be made mandatory for all branches.	Implemented
		2. Reports of sectionals and attendance to be sent to students homes.	Implemented

Table 2. Contd.

Management	a) Amount of investment	After fair discussion in management and SSPIT meeting, Management proposed to be liberal in spending more for the welfare of the college.	Change-in attitude noted
	b) Efficiency of administration	To recruit senior and experienced clerical staff.	Implemented
	c) Scholarship	Scholarship and cash prizes to be given to meritorious students in annual prize distribution function.	Implemented
	d) Provision of financial help for students of weaker class.	Students from weaker section of society to be helped by a guidance cell made by management.	Implemented
	e) Provision of adequate power to principal and faculty	To grant more power to principal and staff regarding discipline of students in college.	Done
	f) Accreditation of college	Proposal for accreditation of college.	In Process ISO-9001:2000 granted
Student faculty relationship	a) Opportunity of informal interaction	Faculty advised to make students feel free even after classes regarding their problems.	Faculty agreed
	b) Student perception of faculty	To distribute and collect students' feedback forms regarding faculty per semester.	Implemented
	c) Counseling session for weak students.	Maintaining the record of poor students by guidance cell made by management.	Implemented
	d) Coaching /Extra classes	To conduct extra classes for the students who fails in sessional examination	Implemented
	e) Attitude of students	Guest lectures by people of different fields for a positive frame work of mind of students.	Lectures Conduced
Examination pattern	a) Pattern of question papers	Strictly in accordance of final term examinations.	Implemented
	b) Predefined syllabus	Academic calendar duly formed to let the students know the distribution of syllabus per sessional.	Implemented
	c) Adequate time between sessional exams	Only one sessional per day.	Implemented
	d) Evaluation criteria	Proper evaluation based on actual performance of student	Executed

Table 2. Contd.

Administration	f) Transparency	Maintaining and submitting weakly performance and attendance sheets	Implemented
	a) Effectiveness	To ensure smooth functioning in administration and clerical block.	Ensured
	b) Discipline and decorum	Discipline and decorum to be maintained by administration with full authority.	Executed
	c) Placement cell with qualified TPO	Training and placement officer (TPO) with technical background and experience to be recruited	Implemented
	d) Emphasis on industrial training	1. TPO to help the students for their Industrial Training.	Executed
		2. Industrial tours to be scheduled yearly by every department.	Executed
	e) Feedback from alumni.	Alumni meet to be organized every year.	Implemented
	f) Provision for qualified counselors	To give TPO, the charge of student counseling.	Implemented

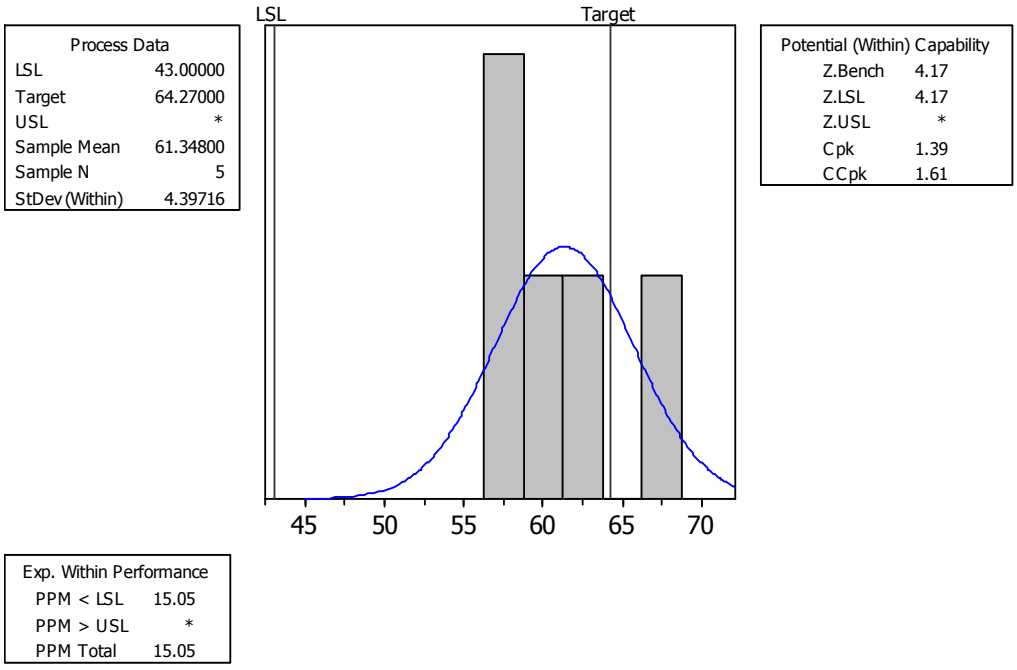

Figure 10. Process capability analysis of passing rate of students after implementing DMAIC methodology.

with Six Sigma strategy to improve productivity.

The project results reveal a need for better faculty, good infrastructure, more financial aid, better student faculty relationship and well planned curricula. The study

could be a paradigm initiative for bringing in improvements on different aspects in existing education system. Technical education institutes should strategically plan to implement Six Sigma for continuous improvement and to achieve more customer satisfaction.

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