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Application of Six Sigma to Improve the Passing Percentage of an Engineering Course

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Abstract

Six Sigma is a data-driven tool used to improve the process quality in either manufacturing or service industry. The objective of the usage of Six Sigma is to obtain less than 3.4 DPMO (defects per million opportunities). DMAIC (Define, Measure, Analyze, Improve and Control) is a methodology applied in this work. There are five phases in the DMAIC. One of the theory subjects named "Basic Thermodynamics" for the third semester of the Mechanical Engineering department is considered for the study. Student's performance in the Semester End Examination (SEE) of the third semester was collected and found that the passing percentage of the students is quite less compared to other subjects. Therefore to improve the students passing percentage in Basic Thermodynamics subject, efforts are made thereby applying the Six Sigma methodology. From the literature survey, the research reveals that for improving the constantly declining pass-percentage of engineering colleges, they needed to have good faculty, better financial condition and the right infrastructure, better student-faculty interaction, and a well-planned curriculum. Six Sigma methodologies help to improve the input quality of students, the teaching-learning process, required classroom facilities, etc. In engineering colleges, defect means, not attaining the marks or grades of the students, which could be due to several reasons. In this work, an attempt is made to improve the passing percentage of students in basic thermodynamics subject by analyzing two years' results and applying the DMAIC technique.

Keywords: *DPMO, DMAIC, Engineering College, Students Passing Percentage, Six Sigma*

1. Introduction

The service sector is experiencing significant growth last few years. Service industries are adding more in number, especially educational institutes. The quality of education will be the most important issue in India in the future and is urgently needed. This is hardly unexpected given how neglected the service industry has been in the context of efforts to enhance quality for decades. In the age of globalization, social attitudes towards education have fundamentally changed. Six Sigma as an improvement approach has recently caught the attention of the service industry. According to Pande et al. (2002), most service organizations operate at sigma quality levels of 1.5 - 3.0 i.e. defect rate between 455,000 and 66,800). The popularity of Six Sigma in service organizations is increasing, especially in banking, hospitals, financial services, airlines, and higher educational institutes. Higher education is now a commercial enterprise and is treated as a marketable commodity.

2.0 Literature Survey

Technical education institutions need cutting-edge auxiliary resource that enhances the standard of the educational process. While a corporation may focus on flaws in its finished goods in industry, flaws in engineering education lead to a declining pass rate among students[1]. Only 7% of

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engineering students in India were found to have employable abilities, according to a recent survey by Purple Leap, a company that specializes in entry-level people management. The remaining pupils lacked technical skills. According to the poll, 80% of students do not possess the necessary problem-solving abilities[2]. It is rather a method of identifying sources of errors and methods of removing them through the use of exceedingly meticulous data collection and statistical analysis[3]. Six Sigma is a discipline that, according to Drake, Sutterfield, and Ngassam (2008), "has changed numerous organizations. They have gone from being at a loss to being profitable thanks to it.

Leaders of universities have to be concerned with improving quality, reducing costs, and meeting customer and other stakeholder requirements[4]. The process of finding the root causes continued by asking detailed questions about each problem causes the root cause was identified. Identification of more detailed levels of causes and organized under related causes or categories. It is observed that prioritizing the causes using the Fishbone diagram model is essential to alleviate the issues related to Poor Academic Performance[7]. Various scholars have written on Six Sigma in academic institutions, but the studies have a very narrow focus. Some of the studies show that the focus on the implementation of Six Sigma is going on to assist university administrators with decision-making on issues such as retaining students in academic programmes based on extensive data analysis, others focus on integrating the Six Sigma methodology into an academic programme, school or college[9].

2.1 Observations and Objectives

From the above literature survey, it is observed that educational institutes are now considered for quality improvement like other service industries. For administrators, it is now a challenge to look forward to quality improvement because human resource is the factor that has to be handled as one of the process parameters from both the teaching side and the learning side. Six Sigma is quite popularly used in educational institutes and the results obtained are admirable. In this work, an engineering institute is selected for the study keeping the objective to improve the passing percentage of students in one of the engineering courses.

3.0 Methodology

The five phases of the DMAIC methodology are followed to implement Six Sigma. The classes are separately considered as A-Division and B-Division, to get a clear view of students from both divisions.

3.1 Define Phase

Project Charter is prepared to state the objectives of this project work. This statement sets out detailed project goals, roles, and responsibilities, and identifies the main stakeholders, and the level of authority of a project team member. The project charter (Table 1) is a document that would consist of a request for a proposal.

Table 1: Project Charter

Project Title:	To improve the pass percentage of students in an Engineering course.
Background:	Few subjects of engineering courses are consistently found to have a lower passing percentage. It affects the overall performance of the students.
Reason	On average, the pass percentage of students is around 89% having a minimum as low as 85%. Hence this study is taken up to improve the pass percentage
Aim of project	By taking the third quadrille we took 88% i.e., At the average of 85%, the students should pass the examination.
Project Leader:	Six Sigma Black Belt.
Project Champion:	Head of the Department
CTQ	It's the ratio of students who passed and students who appeared
Measure	The pass percentage of the Students
Defect	Failure of student
Expected statement	Improve Teaching-Learning Process
Expected : customer benefits	Improved results, better passing percentage, decreased backlogs, and better scope for higher studies/jobs.
Schedule (weeks)	Define: 4 Measure: 3 Analyze: 4 Improve: 5 Control: 5

The SIPOC (Suppliers, Inputs, Process, Outputs, Customers) diagram dictates the scope of work collectively for a team. SIPOC also helps in identifying potential deficiencies between the expectation of process from the suppliers and what expectation of customers from the process at a high level. A SIPOC diagram (Table 2). A process is mapped using SIPOC also helps in identifying potential gaps between suppliers and inputs specifications and between outputs specifications and customer expectations, thus defining the scope for process improvement activities.

A critical-to-quality (CTQ) is the flowchart process of finding out quality features or characteristics of the customer with the perspective to identify the problems. Critical to quality determines the inputs and outputs of processes and

Table 2: SIPOC Diagram

Suppliers	Input	Process	Output	Customers
College/ Management	1. Students 2. Teachingaid's 3. Study materials 4. Teaching staff 5. Infrastructure	1. Students admitted to class 2. Classes are being held according to the syllabus 3. CIE exams are conducted at regular time intervals 4. CIE booklets are evaluated by the concerned staff and marks will be displayed 5. Once CIE marks are displayed final exam will be conducted 6. Pass percentage is being Calculated	Exam result	Students Parents Industries wherever they join.

finds out the path that influences the standard or quality of process outputs.

CTQs correspond to the service characteristics or product features that are comprehensive (Table 3).

3.2 Measure Phase

The data collection plan is developed to provide convenient information on marks obtained by the students to be collected from the Department of Examination (Table 4). The Plan lists 1. Continuous Internal Evaluation (CIE) marks 2. SEE (Semester-End-Examination) marks. Internal Marks include CIE-1, CIE-2, and CIE-3, assignment and External Marks include Semester End Examination. Both internal and external marks are for 50 each. Total marks for the subject will be 100 marks.

The probability plot is a graphical technique for assessing whether or not a data set follows a given distribution and is used to test whether a dataset follows a given distribution (Figure 1 a-l). Based on the data, baseline status is calculated (Table 5)

Table 3: CTQ Specification Table

CTQ	Pass Percentage of the students in "Applied Thermodynamics subject of Mechanical Engineering department
Operational definition of measure: (Passed/Appeared)*100	
Specification	IT SHOULD BE >= 85%
Defect definition	IF IT IS <= 85%

3.3 Analyze phase

Brainstorming is a problem idea-generating technique and helps in problem solving. It is a lateral thing process to generate ideas as possible solutions. The ideas gathered can be crafted into real-time solutions to a problem, and some ideas can help to spark better ideas. It provides a free environment that supports everyone to participate. A brainstorming activity is performed and ideas are collected for the possible solution (Table 6). The ideas or solutions collected are classified into different categories as shown in Table 7.

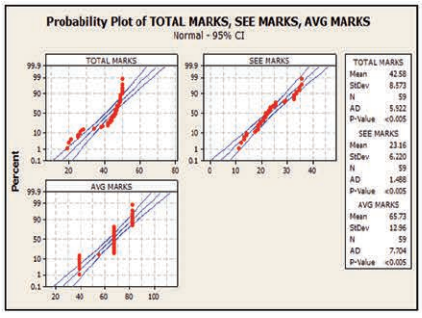
Possible causes for an effect or problem are presented in the fishbone diagram as shown in Figure 2. It helps to structure a brainstorming session and prioritize the causes. It sorts ideas into useful categories and is used when identifying possible causes for a problem. The causes categorized in the above tables are used to draw the fishbone diagram. Accordingly, validation plans and validation causes are studied (Tables 8 and 9).

Table 5: Baseline Status

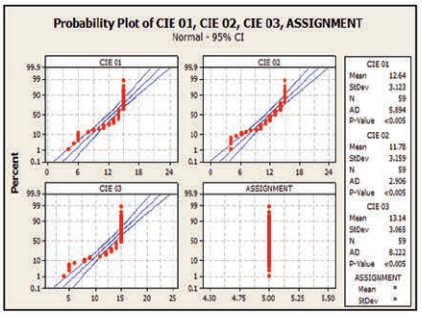
CTQ	Average	DPMO	Sigma level
Pass percentage of the students	87.45 %	1,25,500	2.66

Table 4: Data Collection Plan

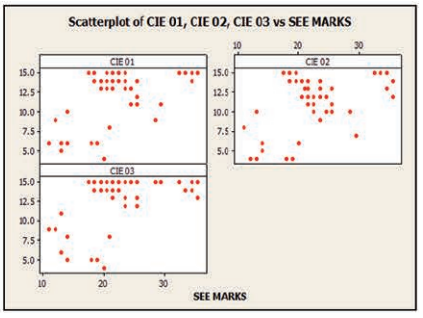
	Characteristics	Datatype	Measure (units)	Sampling	Relatedconditions	Where recorded
1	Score of students in CIE 01	Continuous	—	100%	For each student	Department
2	Score of students in CIE 02	Continuous	—	100%	For each student	Department
3	Score of students in CIE 03	Continuous	—	100%	For each student	Department
4	ASSIGNMENT	Continuous	—	100%	For Each student	Department
5	Score of SEE	Continuous	—	100%	For Each student	Department



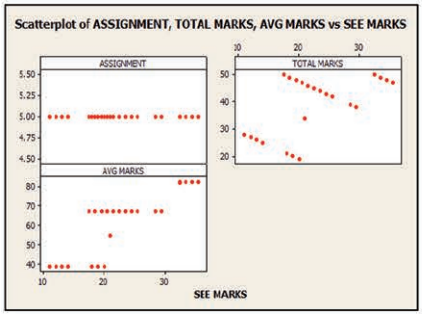
(a) Probability plot for CIE-1, CIE-2, CIE-3 and assignment/A-division



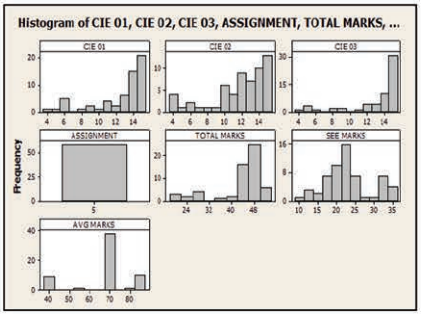
(b) Probability plot for total, SEE marks, average marks/A-division



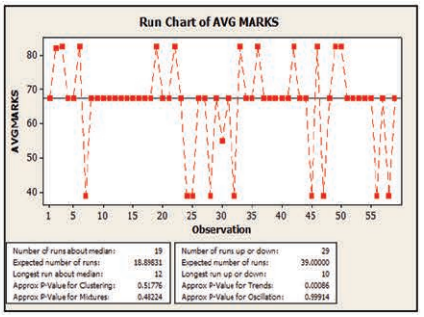
(c) Scatter plot for CIE 1, CIE 2, CIE 3 Marks/A-division



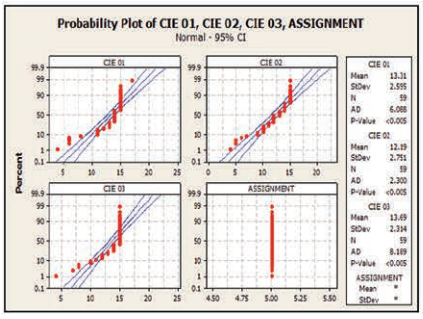
(d) Scatter plot for assignment, total marks, average marks/A-division



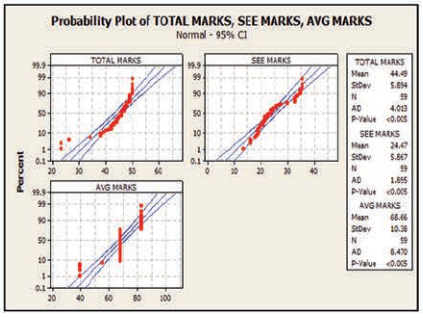
(e) Histogram plot for CIE 1, CIE 2, CIE 3 and assignment, total marks, average marks/A-division



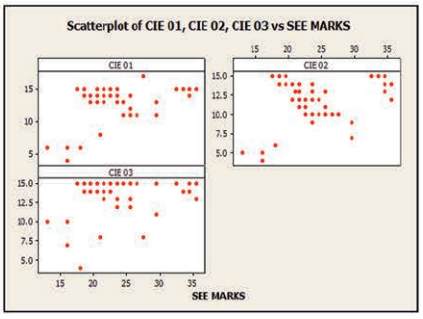
(f) Run chart for average marks/A-division



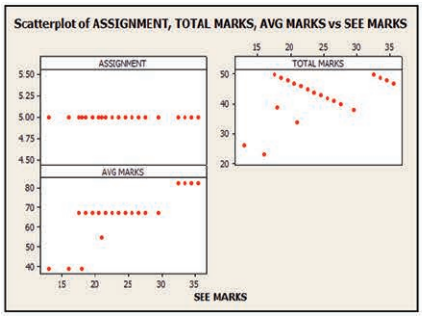
(g) Probability plot for CIE 1, CIE 2, CIE 3 and assignment/B-division



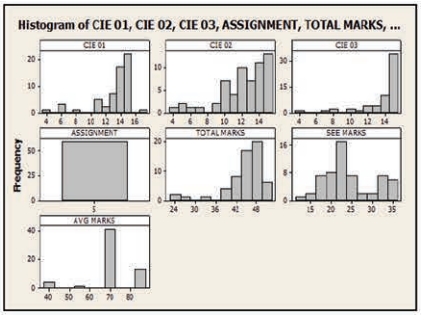
(h) Probability plot for total marks, SEE, average marks/B-division



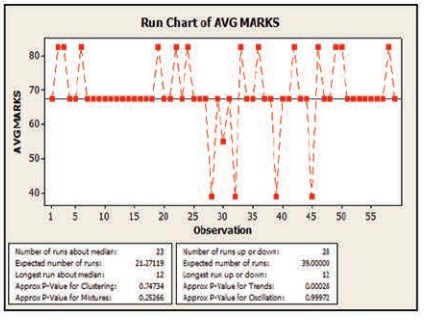
(i) Scatter plot for CIE 1, CIE 2, CIE 3 marks/B-division



(j) Scatter plot for assignment, total, average marks /B-division



(k) Histogram plot for CIE 1, 2, 3, assignment, total and, average marks/B-division



(l) Run chart for average marks /B-division

Figure 1: Probability plot before implementing six Sigma

Table 6: Ideas collected through Brainstorming

	Possible Causes		Possible causes		Possible causes
1	Attitude of learning	26	Exam pattern	51	Referring old question papers
2	Attitude of teacher	27	Extra classes/coaching	52	Regular attendance
3	Blackboard	28	Fluency of language	53	Regularity of teacher
4	Blackboard visibility	29	Grading system	54	Revaluation facility
5	Chalk colour and type	30	Interrelation with students	55	Scheme and solution
6	Classroom size	31	Textbooks in library	56	Sitting arrangement
7	Classroom ventilation	32	Level of language	57	Speed of teaching
8	Class strength	33	Level of understanding	58	Strict evaluation
9	Classes (morning/afternoon)	34	Listening skills	59	Study material available
10	Cleanliness	35	Method of teaching	60	Subject interest
11	Coding and decoding system	36	Mike and speaker	61	Subject is tough
12	Communication problem	37	Motivation by teacher	62	Subject knowledge
13	Computer/laptop	38	New subject	63	Subject (theory/problematic)
14	Conduct of CIE test	39	No material available	64	Supervision
15	Creative teaching	40	Number of CIE tests	65	Syllabus covered
16	Desk and chair	41	Overhead projector	66	The syllabus is too much
17	Dias, podium	42	Photocopy of answer sheet	67	Teacher for discussion
18	Disturbance from passage	43	Projector screen and pointer	68	Teacher notes/handouts
19	Disturbance from side class	44	Question paper lengthy	69	Teachers' interest in a subject
20	Duration of CIE	45	Question paper pattern	70	Teachers' interest in teaching
21	Duration of CIE test	46	Question paper setter	71	Teaching experience
22	Duration of teaching	47	Question paper setting	72	Text/reference books
23	Duster quality	48	Question paper type	73	Whiteboard and marker
24	Evaluation method	49	Reading habit		
25	Evaluator	50	Recounting facility		

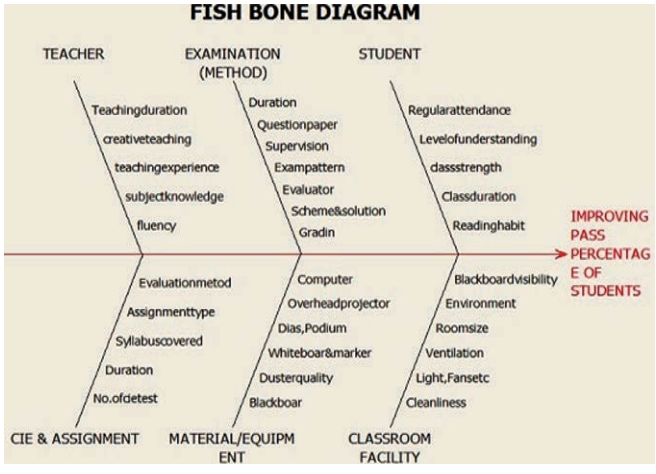


Figure 2: Fishbone diagram

Improve phase

Control phase

From improve phase, the prioritized solutions (Table 10), and possible risks are identified (Table 11). Then implantation plan is done as shown in Table 12. Some of the activities are standardized to monitor the process and minimize the variations. Following are the standard formats made to monitor and control the class timings and evaluation system for internal tests as well as semester-end examinations. Monitor the attendance report for class strength to reach all the students.

Referring to Tables 13 and 14, controlling the teaching-learning process is followed. After implementing Six Sigma, the following plots are done and compared to results obtained before the implementation of Six Sigma.

Table 7: Grouping of Causes

Causes related to Teacher	
Method of teaching	Syllabus covered
Speed of teaching	Duration of teaching
Creative teaching	Extra classes/coaching
Teaching experience	Fluency of language
Subject knowledge	Attitude of teacher
Teaching Aids	Motivation by teacher
Interrelation with students	Referring to old question papers
Causes related to students	
Regular attendance	Reading habit
Level of understanding	Listening skills
Class strength	Subject Interest
Attitude of learning	Background knowledge
Class duration	Level of language
Subject type (theory/ problematic)	Class time (morning/ afternoon)
Causes related to the classroom facility	
Cleanliness	Blackboard visibility
Lights, fans, etc	Teachers voice audibility
Classroom ventilation	Classroom environment
Sitting arrangement	Side class disturbance
Classroom size	Passage disturbance
Causes related to equipment	
Blackboard	Dias, podium
Chalk colour and type	Text/reference books
Duster quality	Teacher notes/handouts
Whiteboard and marker	Desk and chair
Overhead projector	Computer/laptop
Projector screen and pointer	Mike and speaker
Causes related to examination and evaluation	
Duration	Exam hall environment
Question paper pattern	Exam pattern
Question paper setter	Evaluation method
Question paper setting	Evaluator
Supervision	Scheme and solution
Sitting arrangement	Grading system
Revaluation facility	Re-counting facility
Photocopy of answer sheet	Coding and decoding system
Causes related to CIE and assignment	
Number of CIE Tests	Sitting arrangements
Duration of CIE test	Invigilation/supervision
Conduct of CIE test	Evaluation method
Syllabus covered	Scheme and evaluation
Question paper setting	Study material available
Question paper type	Assignment Type

Table 8: Validation Plan

Causes	Specification/ Desired status	Validation method
Class duration	60 minutes	Time table
CIE syllabus	One unit	Teachers report
CIE evaluation	Accurate and common to all	Scheme and solution
Subject syllabus	Complete	Teachers report
Exam evaluation	Accurate and common to all	Exam time table
Class strength	50	Division list

Table 9: Validation Causes

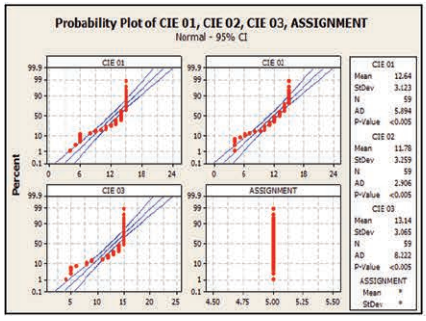
	Validation Causes
1	Speed of teaching and coverage of syllabus
2	Attempt questions and score marks in CIE
3	Variation of marks CIE
4	Attempt questions and score marks in SEE
5	Variation of marks in SEE
6	Teacher-students interaction

Table 10: Prioritising Possible Solutions

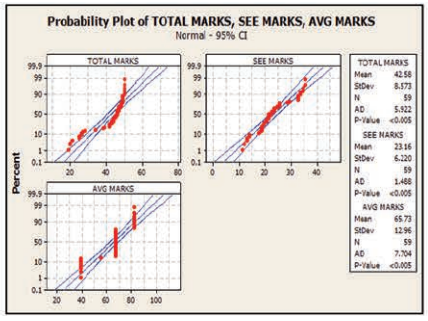
	Validation causes	Solution
1	Speed of teaching and coverage of syllabus	Revise lesson plan
2	Attempting the questions and scoring of marks	Assignments
3	Variation of marks	Review by outsider
4	Attempting the questions and scoring of marks	Assignments
5	Answer maximum questions and score more marks	Review by outsider
6	Closer interaction between teacher and students	Students feedback/ teachers appraisal

Table 11: Possible Potential Risk and Corrective Actions

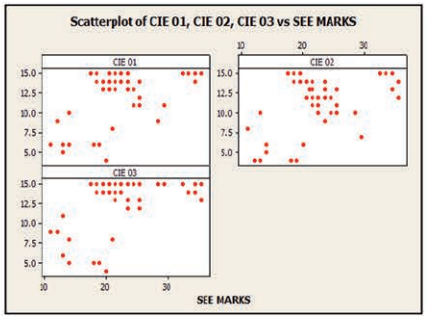
Solution	Potential Risk	Corrective Action
Revise lesson plan	Subject syllabus/ teacher	Change syllabus/ lesson plan/teacher
Assignments	Incomplete/no submission	Marks to be included in the final score
Review by outsider	Extra work/ remuneration	Amongst the students/ cross-checking
Assignments	Incomplete/ no submission	Marks to be included in the final score
Review by outsider	Extra work/ remuneration	To be accepted
Students feedback/ teachers appraisal	Half/improper information	Proper format/method of collection



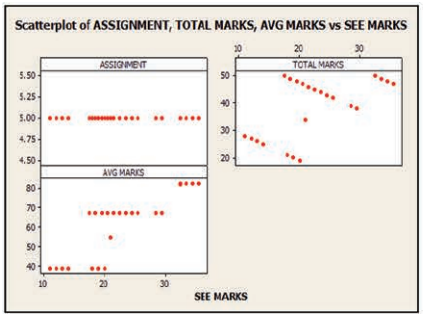
(a) Probability plot for CIE-1, CIE-2, CIE-3 & assignment/A-division



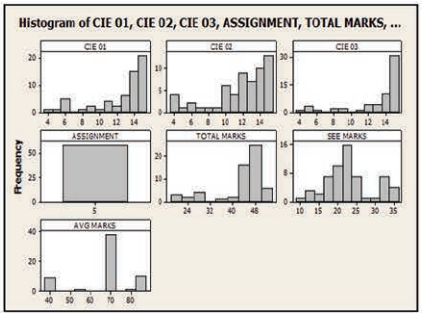
(b) Probability plot for total, SEE marks, average marks/ A-division



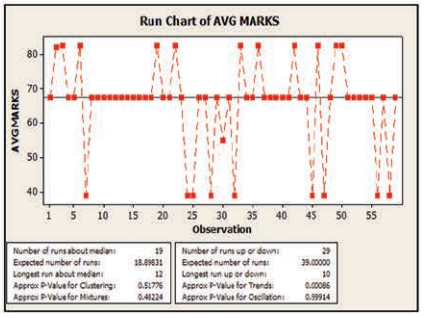
(c) Scatter plot for CIE 1, CIE 2, CIE 3 marks/A-division



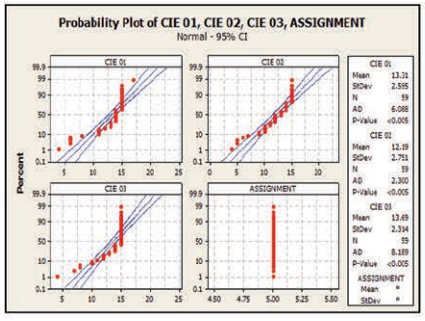
(d) Scatter plot for assignment, total marks, average marks/A-division



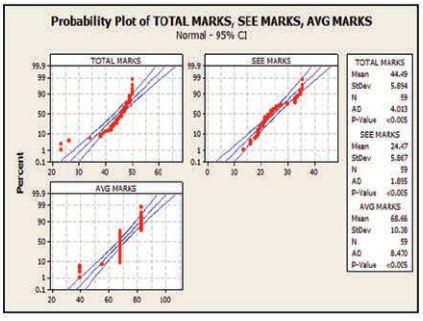
(e) Histogram plot for CIE 1, CIE 2, CIE 3, assignment, total and average marks/ A-division



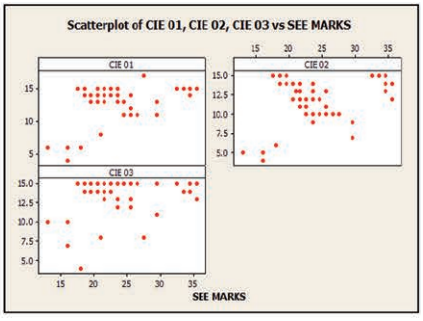
(f) Run chart for average marks/A-division



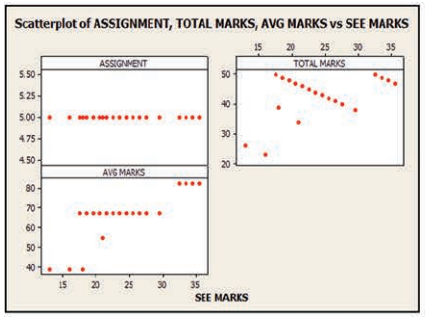
(g) Probability plot for CIE 1, CIE 2, CIE 3 and assignment/B-division



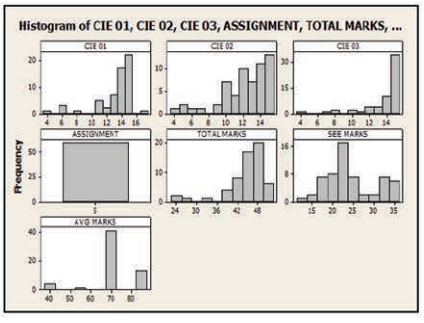
(h) Probability plot for total marks, SEE, average marks /B-division



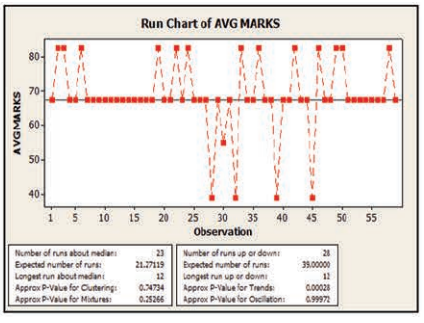
(i) Scatter plot for CIE 1, CIE 2, CIE 3 marks/B-division



(j) Scatter plot for assignment, total, average marks/B-division



(k) Run chart for average marks/B-division



(l) Probability plot for CIE 1, CIE 2, CIE 3, total marks/B-division

Figure 3: Probability plot after implementing six Sigma

Table 12: Implementation Plan

Solution	Steps	Responsibilities
Revise lesson plan	To be issued start of semester	HOD
Assignments	Regular monitor	Teacher+HOD
Review by outsider	During booklet distribution to students	Teacher+HOD
Assignments	Regular monitor	Teacher+HOD
Review by outsider	Monitoring	COE
Students feedback/teachers appraisal	To be analyzed and decided	Teacher and HOD

Target date: follow the calendar of events

Table 13: Class Duration Monitoring

Sr. No.	Date	Time (in)	Time (out)	Topic covered	Signature

Table 14: CIE and SEE evaluation

Sr. No.	USN	CIE Marks			Assignment Marks	SEE Marks
		1	2	3		

Table 15: Results of before and after implementation of Six Sigma

	CTQ	Average	S.D	DPMO	Sigma level
Before	Pass percentage of the students	87.45%	—	1,25,500	2.66
After	Pass percentage of the students	94.11%	—	58900	3.07

4.0 Conclusions

For many companies, positive results are produced from Six Sigma. An attempt has been made to highlight a relationship between the applications of Six Sigma in corporations and technical education. Referring to Table 15, using the Six Sigma technique, the DPMO level has been reduced from 125500 to 58900. The result shows that there is an improvement from 2.66 to 3.07, thus it helped in improving the results of SEE in terms of students passing percentage. The results reveal a need for better faculty, good infrastructure, a better attitude of students towards education, better student-faculty relationship, and well-planned curricula. The study could be a paradigm initiative for bringing improvements to different aspects of the existing education system. Technical education institutes should strategically plan to implement Six Sigma for continuous improvement and to achieve more customer satisfaction.

5.0 References

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