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LEAN SIX SIGMA APPROACH FOR SIMULTANEOUS QUALITY IMPROVEMENT OF COURSES IN HIGHER EDUCATION INSTITUTIONS DURING COVID-19 PANDEMIC

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ABSTRACT

The purpose of this study is to assess whether Lean Six Sigma can improve the quality of teaching-learning processes in higher educational institutions during the Covid-19 pandemic. The integration of e-learning technologies with lean six sigma (LSS). DMAIC stands for five phases of sig sigma project: define, measure, analyze, improve, and control was applied to implement quality assurance in the teaching-learning process. Action research was adopted in 30 courses of a particular engineering programme. The methodology was applied as a course improvement tool, and the challenges encountered during the implementation were also studied. The LSS DMAIC methodology could successfully improve the quality of various courses simultaneously through online mode during the Covid-19 pandemic. The adopted methodology could assist in effectively responding during the present stage of uncertainty and provide stakeholders with guidelines to deal with the post-pandemic era. In terms of practical implications, this study discusses a new approach to improving the quality of the teaching-learning process in higher educational institutions. The LSS DMAIC is applied with the help of online educational and social media platforms for the simultaneous improvement of courses in a particular engineering programme.

Keywords: Lean six sigma, DMAIC, higher education, Covid-19, e-learning.

INTRODUCTION

At present, the world is facing a crucial crisis due to the Covid-19 pandemic and this crisis has particularly affected higher education systems (Raaper & Brown, 2020). Internationally, the crisis has temporarily forced school closures and halted formal education procedures. In general, the current problem is entirely unanticipated in educational research (Hall et al., 2020). Along with Covid-19, higher educational institutions (HEIs) are presently facing severe challenges such as improving graduates' pass percentages and employability. These challenges are also attributed to economic, demographic, social, technological and political changes happening around the world (Nadeau, 2017).

Like any other universities worldwide, Indian universities have now introduced different online teaching and learning methods to support students and tackle the pandemic scenario. In this paper, the authors introduced lean six sigma define measure analyse improve control (LSS DMAIC) methodology with the help of online social media platforms in an academic department functioning under an institution of higher education. The authors applied this method to assure Six Sigma quality in the teaching-learning process. It was also suitable for simultaneous improvement of various courses using mobile learning techniques.

The lean six sigma concept mainly concentrates on customer satisfaction, variation reduction, quality improvement and reduction of cost of poor quality (COPQ). LSS combines lean thinking and six sigma to reduce waste, improve flow, and reduce variation for improving customer satisfaction (Li et al., 2019), which can be applied in any service sector, including HEIs. The results enjoyed by six sigma companies in the service industry are just as impressive as their counterparts in manufacturing industries (Sung, 2003). The LSS DMAIC methodology is usable in teaching to solve most of the learning problems students experience during their course of study. Some studies proved that the six sigma DMAIC tool could be applied directly to improve students' performance in a particular subject (Sontay & Karamustafaoğlu, 2017).

This research aims to apply LSS concepts online for simultaneously improving the academic performance of various courses in a department of an engineering college. According to the earlier research on online education, it was clear that online learning could be as effective as traditional classroom instruction (Katz, 2016). The lean six sigma methodology can be the best choice for higher education institutions to improve their academic activities (Majid & Elmira, 2015). Statistical tools are applied within a performance improvement model known as define-measure-analyse-improve-control or DMAIC (Pyzdek, 2003). The challenges and obstacles experienced during the online implementation of LSS are also discussed in this study. The study used the LSSDMAIC methodology to produce overall improvement of courses.

LITERATURE REVIEW

Lean Six Sigma in Higher Education

Lean is a set of principles and practices developed by Toyota Motor Company to achieve operational excellence (Balzer et al., 2016). The lean approach helped the company achieve process improvement in the early twentieth century by eliminating all types of waste, including non-value-added human motions. Six Sigma is a method of determining weaknesses where the organisation could improve and better serve the customer (Majid & Elmira, 2015). The six sigma quality level narrates to 3.4 defects per million opportunities (DPMO). Achieving the six sigma quality level eliminates causes of quality-related issues and prevents the formation of defects from such problems. The main objectives of LSS are to achieve efficiency and effectiveness in process and improve customer satisfaction (Antony, 2015). Several authors argue that LSS is a simplified and repackaged version of well-known quality management principles. However, the utilisation of LSS in service sectors and other business firms worldwide is widely accepted.

Although the LSS originated in the manufacturing sector, several research studies have applied lean and six sigma to improve service quality in the higher education sector. Due to increased competition, universities have started adopting lean activities to improve process efficiency since the early stages of 2010. However, the implementation of LSS has become visible only in a low number of HEIs thus far (Antony, 2015).

Six Sigma is the best strategy for a quality education system for quality improvement (Ramasubramanian, 2012). Lean and six sigma harmonise with each other, and the former will accelerate six sigma in delivering outstanding results. Six sigma is focused on collecting data to apply statistical tools and techniques to solve problems, and lean is based on using proven principles of knowledge and experience. Integration of lean and six sigma can improve organisations (Sunder & Antony, 2018). The application of lean six sigma in the education sector focuses on improving processes by reducing errors and eliminating defects instead of cutting costs by reducing budgets. Universities are showing interest in LSS to reduce administrative expenses and improve services delivered to students, faculties and researchers (Svensson et al., 2015).

In this study, the student is treated as the HEI customer. Identifying customers and their expectations is a fundamental requirement for achieving customer satisfaction. (Tetteh, 2015). To improve service quality, HEIs must focus on the expectations of students. Reducing waste and improving the efficiency of service delivery have the potential to impact student satisfaction (Douglas et al., 2015). The critical ingredients for successful implementation of LSS in service organisations are committed leadership, organisational cultural change, selection of top talented six sigma team members, supporting infrastructure, proper selection, and prioritisation of projects (Antony et al., 2017). The adaptation of the LSS approach to the university environment is achieved through a mix of university staff and practitioner involvement (O'Reilly et al., 2019). Students should be involved in six sigma and other excellence initiatives to improve the quality of HEIs (Sunder & Antony, 2018).

It is difficult to define and identify 'defects' in HEIs compared to the manufacturing sector due to the complexity of the HEI setting. According to the viewpoints of several authors, the reasons for quality failures in HEIs may be due to students' failure, teaching process failure and poor curriculum design. In this study, a 'defect' in HEI is regarded as a student who could not meet the minimum credit level for a pass set by the University.

Improving Quality with Lean Six Sigma

LSS can produce significant results by constituting a programme or project implementation team. The project team involves team members (TM), green belts (GB), black belts (BB), master black belts (MBB) and champions. The champion has to create the six sigma vision of the company, identify the methods of six sigma, and develop a plan for training to implement the strategies (Erdoğan & Canatan, 2015). The success of the Six sigma project implementation depends on a clear project definition.

The six sigma DMAIC methodology involves five phases. The tools like quality function deployment, FMEA, logic tree, Pareto chart, suppliers-inputs-process-output-customers (SIPOC) diagram, and process flow diagram can be used to define the phases (Tyagi, 2017). The objective of the defined phase of DMAIC is to determine what needs to be improved (Shabad & Belokar, 2016), and this phase identifies the customers and their needs and expectations (Antony, 2015). The defined phase can also utilise a high-level process map to define the problem (Arafeh, 2016). The second phase of the six sigma DMAIC process measures the data and makes it available for analysis and interpretation. Tools like ANOVA, hypothesis test and regression analysis are applied to analyse the data and identify the root causes of defects (Antony, 2015). The improve phase(s) can utilise tools like brainstorming and affinity diagrams (Miski, 2014). The control plan is applied in the control phase to ensure that improvements are sustained and that the ongoing process is monitored (Shabad & Belokar, 2016). Additionally, understanding six sigma business strategy metrics like COPQ, defect rates, and customer complaints is essential for implementing the DMAIC methodology. (Pyzdek, 2003).

While a wide variety of statistical tools and techniques are available as part of the six sigma DMAIC methodology, the proper selection of tools for each phase is essential for successful results. However, there is an absence of standardised procedures for selecting the most suitable tool(s) for a particular situation.

Covid -19 and Online Education

The Covid-19 pandemic has caused a global crisis for education systems, impacting the lives of millions of children and young people (Chapman & Bell, 2020). Universities have incorporated integrated online learning techniques to address the challenges posed by the Covid-19 pandemic. Online education involves digital technologies applied in the teaching-learning process, such as integrating web-based content into all activities related to research on learning management (Katz, 2016). Some universities are implementing online open STEM laboratories to demonstrate complex scientific experiments remotely (Skidmore, 2020). In addition to the current teaching roles of supporters, motivators and counsellors, Covid-19 has generated additional qualification requirements for teachers, such as expertise ininformation technology and social media. Covid-19 has forced teachers to deliver their services remotely through online platforms as they did in their classrooms. (Pelosi & Vicars, 2020). Organisations worldwide responded appropriately to emergency necessities by introducing various e-learning platforms. The sudden transformation into online learning have created severe consequences for higher education quality assurance and open distance learning systems that need to be addressed carefully in the future (Zuhairi et al., 2020). To tackle the challenges of the pandemic, the education systems must redouble efforts and find ways to enable students with fewer resources and other difficulties to continue learning from home (Azorin, 2020).

METHODOLOGY

Based on the research type and conditions, the researchers planned a participatory action research approach to support readers to understand the exact procedure of applying LSS for course improvement. The authors selected the participatory action research model because the focus of the research project was to improve the quality of the teaching-learning process of courses in HEIs through the involvement of stakeholders. The participants of this action research were the primary stakeholders of HEIs, such as students and faculty. The action research method is always relevant to its stakeholders. One of the authors, who teaches at this institute, was a primary stakeholder of the HEI selected for case research. The author had access to all relevant academic records of students. Also, the authors followed all ethical guidelines and rules for collecting data for analysis. The case research entails a detailed analysis of the teaching-learning process of one of the branches of HEI.

The LSS DMAIC process enables the application of participatory action research to solve quality or process problems. (Furterer et al., 2019). The research team identifies the problem, collects and analyses the data in action research, developsa plan for improvement, implements the improved plan, and assessesthe results to verify the upgrades. The LSS DMAIC process involves all the steps associated with action research, including identifying and defining the problem, collecting and measuring data, analysing data, forming improvement plans, and controlling deviations from set planned goals. The research environment involves improving the teaching-learning process (TLP) in 30 courses of a particular department from a reputed technological university in the southern part of India. The students who failed in their earlier attempts at the end-of-semester university examinations were selected for this research project.

The pilot study of research work started in August 2019. The sub-objective of the study was to improve the failed courses of previous semesters by a particular batch of Mechanical Engineering students by applying the six sigma framework. The Covid-19 pandemic caused a mode change in the teaching-learning process during the last stages of research. The pandemic overturned all the conventional norms of the teaching-learning process. To protect the career prospects and higher education opportunities of students with back papers, the University took a challenging decision to "live with Covid" and conducted supplementary examinations in September 2020. The research team took the initiative to provide online classes to selected failed students for them to succeed in their improvement examinations. The team applied the LSS DMAIC methodology for this purpose. This research work was analysed by measuring the results of primary stakeholders—those who attended supplementary examinations.

The participatory action research approach experiments with the teaching-learning process and demonstrates the exact procedure of applying LSS for simultaneous improvement of courses in HEIs with the help of online learning platforms. The team used this improvement philosophy immediately at the end of the pre-final year term of study. The study's objective was to improve the process capability of the teaching-learning process in 30 out of 41selected courses.

The methodology for implementing the LSS DMAIC in one of the departments of HEI is detailed as follows.

- Prepare the organisation for six sigma implementation, re-designation, and training.
- Formation of cluster and LSS team.
- DMAIC implementation.

In this LSS DMAIC process, the research team developed a project charter in the define phase to outline the mission, scope, and statement of the problem (Pyzdek, 2003). A 'project charter' was prepared to present the business needs to be addressed by the project and the details of the authorised person responsible for the action. The team developed a plan to collect data required to measure the current status of the process in the measure phase. Statistical tools such as bar charts and DPMO – Six Sigma tables (Sung, 2003) were used for data measurement and graphical representation. In the analyse phase, the cause and effect diagram and Pareto analysis diagram were applied to analyse the data collected and identify root causes of problems. An 'online improvement plan' was prepared and applied in the improvement phase to suggest the necessary improvements in the process. Finally, in the control phase, a 'control plan' was prepared and implemented to maintain process improvements and control deviations from the mission statement set in the Define phase of LSS DMAIC.

Table 1

Responsibilities of Six Sigma Team

Role and re-designation	Present designation	Routine functions	Six Sigma responsibilities
Champion	Head of Department	Subject allocation, monitoring of teaching-learning process.	Resource allocation, faculty training and development, guidance, and motivation.
Master Black Belts (MBB)		Six Sigma trainer and consultant.	Training of all stakeholders, application of Six Sigma tools and techniques.
Black Belts (BB)	Faculty expert insubjects	Academic work.	Motivational techniques for subject improvement.
Green Belts (GB)	Faculty members	Preparation of teaching aids.	Processing improvement.

Prepare the Organization for Six Sigma Implementation, Re-designation, and Training

The six sigma project team involves master black belt (MBB), black belts (BB), green belts (GB) and team members™ (Pyzdek, 2003). The authors constituted a project implementation team with the head of the Mechanical Engineering Department as the champion, a senior faculty member with knowledge in LSS as the MBB, and a faculty member with sufficient experience in the course as the BB. The supporting faculty member who was redesignated as GB had assisted the BB in some of the courses. All other team members were trained in the basics of LSS, statistical tools, motivational tools and project identification tools. The responsibilities of the six sigma team are described in Table1.

Formation of Cluster and LSS Team

To award a degree in Mechanical Engineering at the university level, a student has to undergo a teaching-learning process in 41 theory courses, 14 practical courses, design projects, seminars and final projects during a 4-year course period. The university conducts examinations in 41 theory courses. The objective of this research is to improve the pass percentage by reducing the course failure rate. A 'defect' in HEI is considered as astudent who did not meet the minimum credit level set by the University for passing the subject. Upon analysis of the results, the research team found that 30 courses needed improvement to achieve zero defects for the current batch of students.

The team created eight subject clusters to accommodate these courses based on similarities in course content and relations among the teaching and learning process. The clusters were nominated and numbered serially from Cluster1 to Cluster 8. Cluster 1 brought together four thermal-related courses such as (course code and name of course) ME204 Thermal Engineering, ME205 Thermodynamics, ME302 Heat and Mass Transfer, and ME 405 Refrigeration and Air Conditioning. The Six sigma project team activities under each cluster were headed by a senior faculty member in the course as a BB. The guidance and training in statistical tools and techniques for BB and other members were conducted by an MBB. In the six sigma project in Cluster1 (SSPC1) project, BB in Thermal courses was supported by course tutors in thermal engineering subjects as GBs.

The project team's objective was to ensure 'zero defect' in courses of the cluster. The application of LSS can achieve this by reducing the 'defect rate' in the course and thereby ensuring six sigma quality in students' academic performance. The research team constituted an LSS implementation team with nine faculties. Faculty1, who knows six sigma tools and techniques, was designated as a master black belt. Other faculties, starting from Faculty 2 to Faculty 9, were assigned the designation of black belt to lead the project team for their respective clusters. Figure 1 shows the details of clusters constituted by combining similar courses. The number of defects identified and the faculty authorised for each cluster are also described in the figure.

DMAIC Implementation

The LSS DMAIC framework applied in a particular department of technical education and various statistical quality control tools utilised in each phase are described as follows. The subject of study involved 58 students. The study period was one academic year, which began at the end of the programme's third year. The team obtained examination results from department records and the recently published online examination results. The count of failed students, represented as 'defects' in each examination, was measured and analysed as part of the LSS DMAIC implementation.

Figure 1

List of Clusters and Count of Failures

Sl.No	CLUSTER	Number of Failures	MBB	BB	GB
CLUSTER 1 (Thermal)					
1	Thermodynamics, TD	6	Faculty1	Faculty2	Faculty 10
2	Thermal Engineering, TE	9			
3	Heatand Mass Transfer, HMT	7			
4	Refrigeration and Air Conditioning, RAC	17			
CLUSTER 2 (Design)					
1	Computer-Aided Design and Manufacturing, CAD	6	Faculty1	Faculty3	NIL
2	Design of Machine Elements I, DMEI	13			
3	Design of Machine Elements II, DMEII	**0**			

(continued)

Sl.No	CLUSTER	Number of Failures	MBB	BB	GB
CLUSTER 3 (Manufacturing)					
1	Metallurgy & Materials Engineering, MMSC	5	Faculty1	Faculty4	NIL
2	Manufacturing Technology, MT	7			
3	Machine Tools and Digital Manufacturing, MTDM	10			
4	Advanced Manufacturing Technology, AMT	15			
5	Non-Destructive Testing, NDT	0			
CLUSTER 4 (Management)					
1	Principles of Management, POM	4	Faculty1	Faculty5	NIL
2	Supply Chain and Logistics Management, SCM	0			
3	Business Economics, BE	7			
CLUSTER 4 (Management)					
4	Life skills, LS	2			
5	Advanced Energy Engineering, AEE	0			
6	Industrial Engineering, IE	0			
7	Human Relations Management, HRM	0			
CLUSTER 5 (Mathematics and applied sciences)					
1	Calculus, CALCULUS	2	Faculty1	Faculty6	NIL
2	Linear Algebra & Complex Analysis, LACA	3			
3	Probability Distributions, Transforms and Numerical Methods, PROB	0			
4	Differential equations, DE	2			
5	Computer Programming &Numerical Methods, CPNM	5			
6	Engineering Physics, PHYSICS	1			
7	Engineering Chemistry, CHEMISTRY	1			
8	Basics of EE, BEE	0			

(continued)

Sl.No	CLUSTER	Number of Failures	MBB	BB	GB
CLUSTER 6 (Mechanics)					
1	Introduction to Mechanical Engineering Sciences, IME	0	Faculty1	Faculty7	NIL
2	Basics of Mechanical Engineering, BME	0			
3	Engineering Mechanics, EM	2			
4	Mechanics of Solids, MOS	6			
5	Advanced Mechanics of Solids, AMOS	15			
CLUSTER 7 (Fluids)					
1	Mechanics of Fluids, MOF	11	Faculty1	Faculty8	NIL
2	Fluid Machinery, FM	11			
3	Mechanics of Machinery, MOM	4			
4	Dynamics of Machinery 2-1, DOM	8			
5	Compressible Fluid Flow, CFF	10			
CLUSTER 8 (Miscellaneous)					
1	Electrical Drives &Control for Automation, EDCA	12	Faculty1	Faculty9	NIL
2	Metrology and Instrumentation, MI	8			
3	Mechatronics	22			
4	Automobile Engineering, AE	0			

The details of the five phases included in the LSS DMAIC are described as follows:

Define Phase

The research team prepared project charters for all the 30 courses selected for improvement in the Define phase. The project charter prepared for one of the courses under Cluster 1(Thermal) is shown in Figure 2.

Figure 2

Project Charter for Thermal Cluster

Project Name/ Number	Improvement of academic performance of students inCluster 1 (Thermal Engineering) SSPCluster1			
Sponsoring Organisation	Engineering College(EC)			
Project Sponsor	Name: HOD	Phone:		
	Office Location: College	Mail Stop:		
Project Black Belt	Name: Faculty 2	Phone:		
	Office Location: College	Mail Stop:		
Project Green Belt	Name: Faculty10	Phone:		
	Office Location:	Mail Stop:		
Team Members (Name)	Title / Role	Phone	Office Location	Mail Stop
	HOD		Engineering College	
	BB-Faculty2		Engineering College	
	MBB-Faculty3			
Principal Stakeholders	Title / Role	Phone	Office Location	Mail Stop
Students of ME dept			CEMP	
Date chartered:	Project Start Date:	Target Completion Date:		

(continued)

Project Name/ Number	Improvement of academic performance of students inCluster 1 (Thermal Engineering) SSPCluster1	
	1 January 2020	30 April 2020
Revision: N/C:	Number: 0	Date
	Sponsor Approval Signature:	
Project Name/ Number:	Improvement in academic performance of students in Cluster 1(Thermal Engineering)	
Project Mission Statement	The project aims to achieve a 100% pass rate in thermal engineering courses within the Mechanical Engineering Department by ensuring a zero defect rate with six sigma capability.	
Problem Statement	In the last two years, the failure/defect rate in thermal engineering courses hassignificantly increased, leading to poor performance in the overall results of the department. Consequently, the departments' poor results have affected the academic performance of the institute at the University.	
Project Scope	Six sigma project will improve students' academic performance by ensuring a 100% pass rate in thermal engineering subjects.	
Business needs to be addressed by this project	Poor results are affecting the institute's reputation, thereby reducing the intake of students. The reduction in intake also reduces revenue.	
Product or service created by this project (Deliverables)	Improvement in academic performance of students in thermal engineering courses.	
Resources authorised for this project	Faculty 2 (Faculty handling thermal engineering courses under Cluster1)	

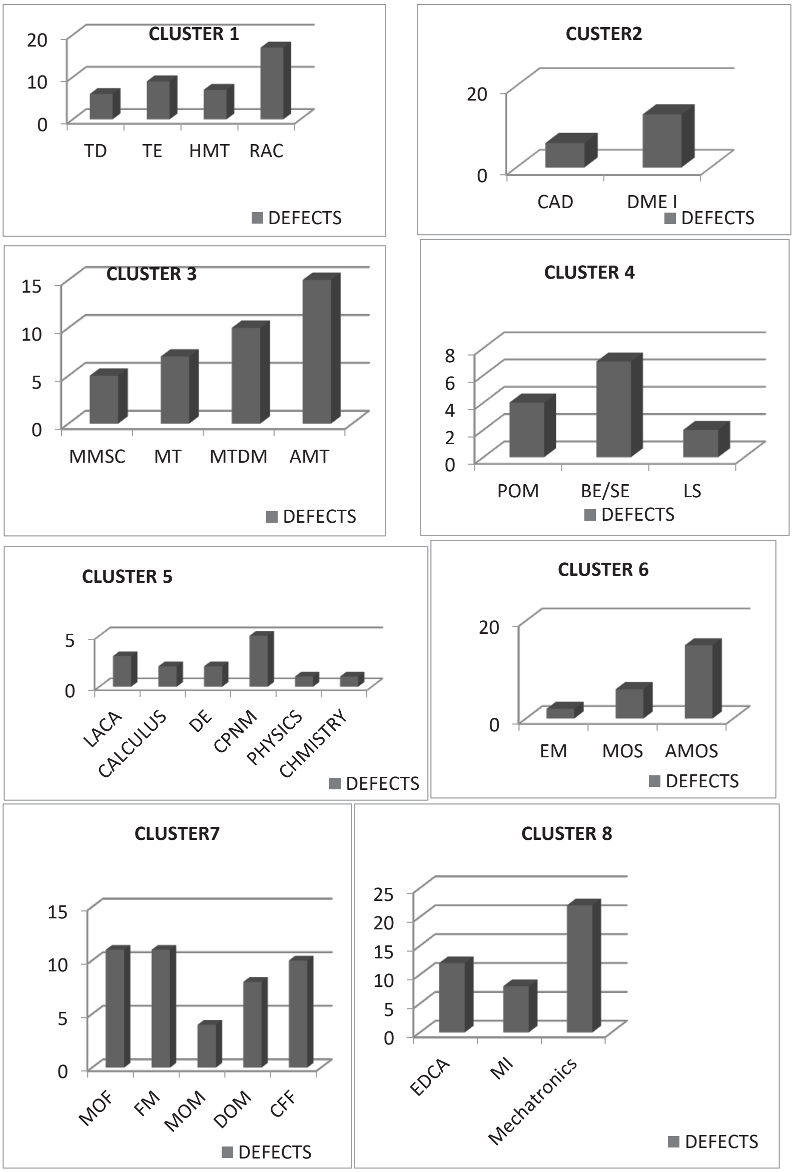
The project charter defined and described the scope, mission and resources authorised for each project identified for improvement.

Measure Phase

The bar chart showing defects among various clusters was prepared in the Measure phase.

Figure 3

Bar Chart of Defects in Clusters



The number of defects identified in various courses under eight clusters is shown in Figure 3. The team used the defects per million

Table 2

Process Capability of Thermal Cluster

Product / Process/ Subject	Defect	Unit	Opportunity	Total Opportunity	DPU	DPO	DPMO	Process Capability (Sigma level from tables)
	No. of failures (2)	No. of batches (3)	No. of students/ batch (4)	(5)= (3)X(4)	(6)= (2)/(3)	(7)= (2)/(5)	(7)X 10,00,0000	
SSS3ME205TD	06	1	58	58	06	0.10344827	103,448	2.76
SSS4ME204TE	09	1	58	58	09	0.15517241	155,172	2.51
SSS7ME302HMT	07	1	58	58	07	0.12068965	120,689	2.67
SSS7ME405RAC	17	1	58	58	17	0.29310344	293,103	2.04

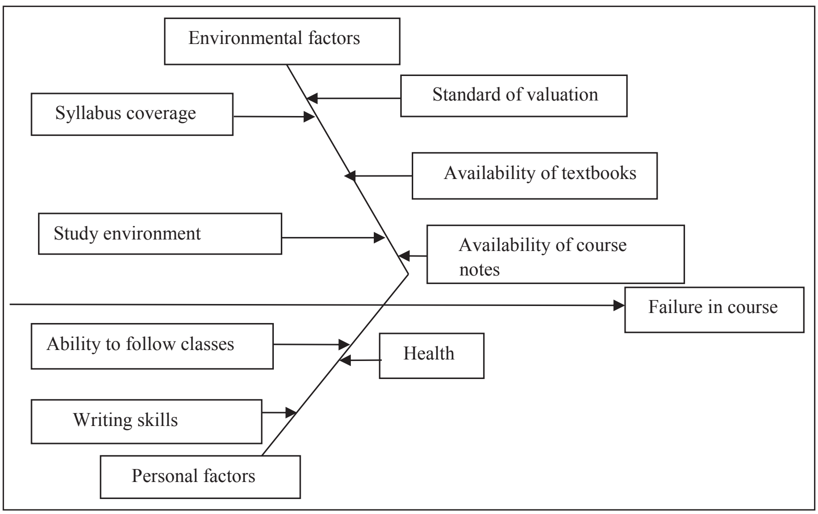
opportunities (DPMO)-Six Sigma table (Sung, 2003) and measured the process capability for the various clusters by calculating the present six sigma value. The process capability measured for the various courses under the Thermal cluster is presented in Table 2.

Analysis Phase

The team analysed data collected in the measure phase to identify the root causes of failure in courses.The brainstorming sessions among the faculty members and students helped identify the factors affecting students' failure in the University examinations. Figure 4 shows the cause and effect diagram on reasons for failure. The environmental factors and students' behavioural or personal factors also affected the students' failure of courses in the University examinations.

Figure 4

Cause and Effect Diagram



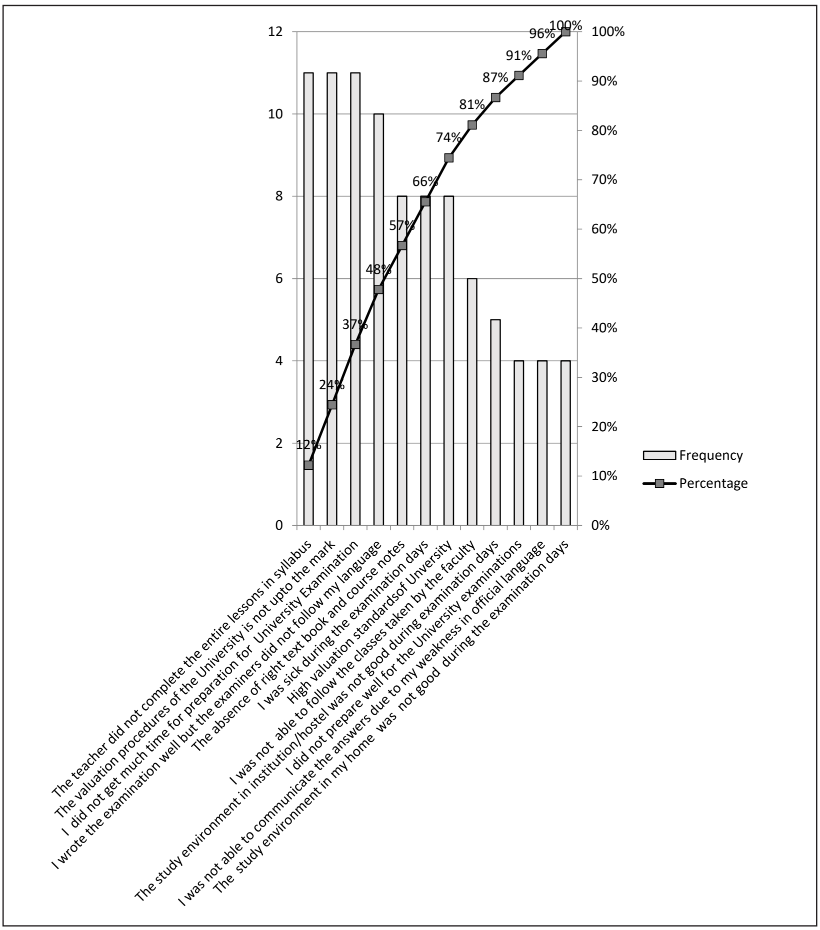
Analysis by Online Survey

To determine the vital few among the trivial many, the research team conducted a Pareto analysis with the help of an online survey questionnaire. The survey was designed in Google Forms for online circulation among the stakeholders. It identified some potential failure modes, areas of improvement, and root causes of failure during the previous University examinations concerning the selected students.

In general, non-completion of the syllabus by the faculty, valuation standards of the University, and time utilised for preparation for University examinations were identified as the major factors for failure, according to the students' point of view. The Pareto analysis revealed that approximately 60 percent of the problems encountered were due to 41.66 percent of the causes. Other factors such as the availability of textbooks and course materials, the ability of students to follow classes, proficiency in the official language, writing skills, and health issues also resulted in failure in some courses for the students. Figure 5 shows the Pareto analysis diagram.

Figure 5

Pareto Analysis Diagram



Improve Phase

In the improve phase, the project team developed an improvement plan to eliminate defects and failures based on the key variables identified in the Analysis phase by conducting a brainstorming session among the team members. The objective of the project team was to prepare the 'failed students'to attend the University examinations scheduled from 9 September to 6 November 2020. Based on the factors identified in the Analysis phase, it was necessary to address the completion of the entire syllabus and distribution of course notes for various subjects before the examinations,which were conducted during Covid-19.

Online Improvement Plan

As part of the improvement plan, each cluster created an online social media group by collecting the mobile phone numbers of 'failed students' under them. This group shared online copies of course notes and textbooks, as well as online videos covering various portions of the syllabus. The cluster team encouraged the students through motivating lectures and calls. Students under each cluster were encouraged to clarify their doubts and requirements through this group. The team conveyed examination-related news, such as the date and times of examinations, to the students through online messages. Important questions to be studied and solved questions from previous examinations were circulated through the online platforms. Each cluster was managed by the faculty in charge of the cluster, designated as BB. The BB of each cluster followed up on the progress of the improvement plan for the cluster. The cluster remained active until the University examinations and collected valuable suggestions and feedback. For example, the online improvement plan procedures for course ME405 Refrigeration and Air Conditioning (RAC) under Cluster 1, Thermal Engineering, are detailed as follows.

1. Created a new group in WhatsApp for course, ME4052020 RAC.
2. Added participants.
(a) Added mobile numbers of faculty in charge (MBB), Faculty2 (BB) and Faculty10 (GB).
(b) Added mobile phone numbers of students who failed in RAC.
3. Renamed the new group as ME4052020 RAC.
4. Sent message on objective of the group.

5. Shared the syllabus.
6. Shared course material on lecture videos for all modules contained in the syllabus.
7. Shared relevant questions and solved problems.
8. Shared previous question papers with answers.
9. Conducted trial tests.
10. Shared all University notifications regarding examinations.
11. Shared motivational messages.
12. Collected feedback after the exam.

The team repeated the procedure for all other courses selected for improvement, as detailed in Figure 1.

The Control Phase

In this phase, the team prepared a control plan to monitor the ongoing process and to maintain sustainability in improvements. The features of the control plan are detailedin Figure 6. As mentioned in the control plan, the owner was authorised to take necessary action to correct deviations from the prepared plan.

RESULTS AND DISCUSSIONS

The LSS DMAIC was applied successfully in online mode to improve the quality of various courses spread over semesters 1 to 7 under a particular stream of engineering with the support of e-learning technologies. The LSS methodology created a data-oriented structure for periodic review and analysis. The effect of the implementation of LSS DMAIC during the Covid-19 crisis was measured by analysing the results of one of the courses, ME405 RAC in Cluster 1. Based on the results published in November 2020, 13 out of 17 students passed their supplementary examinations conducted by the University, changing the sigma value from 2.04 to 3.12. Thus, significant improvement in process capability is possible through the application of lean six sigma DMAIC methodology in online mode. Consequently, the integration of LSS DMAIC and e-learning technologies could enhance the teaching-learning process of HEIs even during the Covid-19 pandemic.

Figure 6

Control Plan

Process steps	Control Mechanism	Measure/Metric	Criticality (H M L)	Action taken if problems occur	Owner
Correct personal factors-time	Control of preparation time.	Did they utilise study time effectively?	H	Online class on motivation and time management. Monitoring of study time.	Faculty in charge of respective clusters
Correct personal factors- writing and communication	Writing skills and communication of course contents.	Oral language.	H	Writing assignments and online submission. Corrective actions. Training on English writing skills.	Faculty in charge of career guidance
Ensure availability of textbooks and course materials	Textbooks and course material.	Feedback of customers regarding availability of textbooks and course materials.	H	Use web-based platform to distribute online course materials and e-books to cover the entire syllabus.	Faculty in charge of cluster
Student satisfaction	Improvement incustomer satisfaction.	Voice of primary stakeholders regarding online classes.	H	Online student satisfaction surveys via Google Forms.	Project team leader
Faculty satisfaction	Improvement infaculty satisfaction.	Voice of faculty regarding the availability of resources for online teaching.	M	Online Faculty satisfaction surveys via Google Forms.	Project team leader

The findings from the study revealed the following challenges for the practical implementation of LSS in online mode for the simultaneous improvement of courses in HEIs.

- Training must be provided to faculty in online statistical tools of LSSDMAIC.
- Faculty require more time and effort for the preparation of course materialsfor online teaching.
- Patience and discipline of students will be crucial factors for the success of online learning.
- A higher initial investment is needed for the purchase of equipment such asmobile phones, tablets, and laptops for online learning compared to conventional learning methods.
- Maintenance costsare high for ensuringuninterrupted internet connectivity.
- Intellectual property rights ofteaching materials available online are applicable in online teaching.
- It is challenging to authenticate students attending online classroom learning.
- It is challenging to maintain students in online classrooms due to the distracting nature of social media and other entertainment platforms.
- It is difficult to identify students who need special attention.

CONCLUSION AND IMPLICATIONS

Integrating e-learning technologies and lean six sigma could simultaneously improve the quality of courses in any environment, including situations like the Covid-19 pandemic in HEIs. The cluster teams created under the LSS DMAIC methodology motivate students to achieve better results in final examinations. Online digital technologies applied in the teaching-learning process, such as the integration of social media platforms, could assist HEIs in managing situations like Covid-19. Although the transition to online learning hasposed challenges to quality assurance in higher education learning systems, integrating lean six sigma DMAIC technologies with e-learning platforms can address the challenges faced by HEIs during the pandemic by creating a framework for process improvement. Factors such as the commitment of management, participation of all employees with patience, and importance are crucial for the successful online implementation of LSS in HEIs. Management must train officials in the concept of LSS. Some challenges associated with online teaching include more preparation time for teachers, recognizing and identifying students attending the classes, higher initial investment and increased maintenance costs. The simultaneous course improvement was applied to one of the institution's branches. Further, in-depth studies will be conducted on a larger scale to validate the results. The application of simultaneous improvement strategies in the teaching-learning process to all other branches of the institution can enhance the overall performance of the institution. The study highlights e-learning strategies that can be applied in HEIs to excel in their teaching-learning process during the Covid-19 pandemic. Issues related to connectivity, portability and accessibility of mobile devices need to be addressed for the successful deployment of LSS DMAIC in HEIs during the Covid-19 pandemic.

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