
Quality Assurance in Higher Education through Six Sigma DMAIC: Aligning Learning Outcomes with NEP 2020

Nimbale S. M.
Assistant Professor

Department of Statistics, Karmaveer Bhaurao
Patil Mahavidyalaya, Pandharpur, India
Sharad.nimbale@gmail.com

Satyam Chikkalli,
Biostatistician,

LifeSan Clinical Research,
Mumbai
satyamchikkalli14@gmail.com

Abstract:

The National Education Policy (NEP) 2020 emphasizes outcome-based education and continuous quality assurance in higher education. However, many institutions experience variability in student learning outcomes, with a significant proportion of students failing to meet minimum academic standards. This study applies the Six Sigma DMAIC (Define–Measure–Analyze–Improve–Control) methodology to improve learning outcomes in higher education. The analysis is based on internal assessment data of 200 undergraduate students. Students scoring below 40 marks were identified as not meeting the required learning standards. Descriptive statistics and defect rate analysis were used to assess baseline performance. Pareto analysis and Fishbone diagrams identified the key causes of poor academic performance. NEP 2020-aligned interventions, including improved teaching strategies and remedial support, were implemented. A paired t-test and control charts were used to evaluate the effectiveness and stability of improvements. The results indicate significant improvement in student performance, demonstrating the effectiveness of Six Sigma DMAIC as a quality assurance framework under NEP 2020.

Key words: *Six Sigma DMAIC, Quality Assurance, Higher Education, Learning Outcomes, Outcome-Based Education, NEP 2020;*

1. Introduction

Quality assurance has emerged as a central concern in higher education systems worldwide due to increasing expectations related to accountability, learning effectiveness, and stakeholder satisfaction. In India, the National Education Policy (NEP) 2020 marks a significant shift from input-based education to outcome-based education, emphasizing measurable learning outcomes, continuous assessment, and institutional quality enhancement (Government of India, 2020). Despite these policy reforms, many higher education institutions continue to face challenges such as uneven student performance, high failure rates, and substantial variation in learning outcomes across courses and cohorts. These challenges highlight the limitations of traditional quality assurance mechanisms, which are often descriptive in nature and lack systematic, data-driven process control (LeMahieu et al., 2017).

Six Sigma, originally developed as a quality improvement methodology in manufacturing and service industries, has gained attention as a robust framework for reducing process variability and improving performance through statistical thinking and structured problem-solving (Montgomery, 2019; Antony et al., 2021). The Define–Measure–Analyze–Improve–Control (DMAIC) cycle of Six Sigma offers a systematic approach for identifying performance gaps, analyzing root causes, implementing targeted interventions, and sustaining improvements over time. Recent studies indicate that Six Sigma DMAIC can be effectively adapted to educational contexts, including curriculum design, teaching–learning processes, assessment systems, and student performance monitoring (Arafeh et al., 2021; Abdulla & Kavilal, 2022).

However, applying Six Sigma in higher education presents unique challenges due to the intangible nature of educational outcomes, diverse stakeholder expectations, and the shared responsibility of students and faculty in the learning process (Hoerl & Bryce, 2018; Holmes et al., 2019). Nevertheless, empirical evidence suggests that when appropriately contextualized, Six Sigma can significantly enhance academic quality, reduce performance variability, and improve student achievement (Yu & Ueng, 2012; Sabtu et al., 2023). Importantly, the principles of Six Sigma—continuous improvement, data-based decision-making, and accountability—closely align with the core objectives of NEP 2020, including outcome-based education, learner-centric pedagogy, and institutional excellence.

In this context, the present study applies the Six Sigma DMAIC methodology as a quality assurance framework to align student learning outcomes with the goals of NEP 2020. By systematically analyzing academic performance data and implementing evidence-based interventions, the study aims to demonstrate how Six Sigma can support sustainable quality improvement in higher education institutions.

2. Literature Review:

Quality assurance in higher education has become a global priority due to increasing demands for accountability, transparency, and improved learning outcomes. Traditional quality assurance mechanisms primarily focus on accreditation, audits, and compliance-based evaluation, which often fail to capture process-level inefficiencies affecting student learning (LeMahieu et al., 2017; Cudney et al., 2018). The National Education Policy (NEP) 2020 further strengthens this concern by emphasizing outcome-based education, continuous assessment, and learner-centric approaches to ensure holistic student development. However, despite policy reforms, higher education institutions continue to experience uneven academic performance, high failure rates, and significant variation in learning outcomes among students (Pal, 2022; Yusop et al., 2022).

Six Sigma is a data-driven quality improvement methodology designed to reduce process variation and improve performance through structured problem-solving techniques (Montgomery, 2019). The DMAIC framework—Define, Measure, Analyze, Improve, and Control—has been widely applied in manufacturing and service sectors and has gradually gained attention in educational settings. Studies by Arafeh (2016) and Arafeh et al. (2021) demonstrated that Six Sigma DMAIC significantly improves student academic achievement by identifying root causes of poor

performance and implementing targeted interventions. Antony et al. (2021) further confirmed the adaptability of DMAIC in educational institutions by improving instructional quality and process efficiency.

Recent investigations indicate that Six Sigma tools such as descriptive statistics, Pareto analysis, Fishbone diagrams, and control charts are effective in monitoring academic processes and sustaining improvements (2022; Sabtu et al., 2023). These studies highlight the potential of DMAIC as a systematic quality assurance framework capable of addressing variability in student learning outcomes.

Despite its benefits, implementing Six Sigma in higher education presents several challenges. The intangible nature of learning outcomes, diverse stakeholder expectations, and shared responsibility between faculty and students complicate the direct application of industrial quality models (Hoerl & Bryce, 2018; Holmes et al., 2019). Additionally, academic institutions often lack standardized performance metrics and continuous monitoring mechanisms, limiting the effectiveness of quality improvement initiatives (Biju & Nair, 2017; Jayamohan & Bhasi, 2021). Nevertheless, recent studies emphasize that contextual adaptation of DMAIC can overcome these challenges and support sustainable academic quality improvement (Shanshan et al., 2022; Taraza et al., 2023).

Although NEP 2020 advocates outcome-based education and continuous quality enhancement, many higher education institutions continue to face persistent variability in student learning outcomes. A considerable proportion of students fail to achieve minimum academic standards due to factors such as ineffective teaching methods, irregular attendance, insufficient assessment feedback, and lack of remedial support. Existing quality assurance mechanisms are largely descriptive and reactive, lacking a structured, data-driven approach for identifying root causes and sustaining improvements in academic performance.

The review of recent literature reveals that while Six Sigma DMAIC has been successfully applied in isolated educational contexts and specific courses, there is limited empirical research integrating Six Sigma DMAIC with NEP 2020-aligned learning outcomes in Indian higher education institutions. Most existing studies focus on international settings, single-subject interventions, or general quality improvement without explicit policy alignment. Furthermore, limited attention has been given to using statistical process control tools to ensure the sustainability of academic improvements. Therefore, a clear research gap exists in developing and empirically validating a Six Sigma DMAIC-based quality assurance framework that systematically aligns student learning outcomes with the objectives of NEP 2020, which the present study seeks to address.

3. Six Sigma and DMAIC in Education

Six Sigma, a data-driven methodology traditionally used in manufacturing and service industries, has gained prominence in educational quality assurance due to its structured approach to process improvement (Antony, 2014). The DMAIC framework—Define, Measure, Analyze, Improve, Control—provides a systematic method to enhance institutional processes, including curriculum delivery, assessment methods, and learning outcomes (Pande et al., 2000). In the context of higher education, DMAIC can align institutional objectives with the National Education Policy (NEP)

2020, which emphasizes holistic, learner-centered education and continuous outcome-based assessment (MHRD, 2020). By defining learning goals clearly, measuring student performance through formative and summative assessments, and analyzing gaps in pedagogy, institutions can implement targeted interventions. Improvement strategies may include faculty development programs, innovative teaching methods, and digital tools to enhance learning efficacy. The control phase ensures that these improvements are standardized and sustained over time, fostering accountability and continuous quality enhancement. Six Sigma metrics, such as Defects Per Million Opportunities (DPMO), can quantify deviations in learning outcomes, ensuring objective evaluation. Integrating Six Sigma with NEP 2020's emphasis on experiential and multidisciplinary learning supports evidence-based decision-making in educational planning. Research indicates that applying DMAIC in education enhances operational efficiency, reduces academic disparities, and strengthens student engagement. Moreover, systematic process improvement fosters a culture of excellence, which aligns with NEP's vision of promoting research, innovation, and skill development. Higher education institutions adopting Six Sigma benefit from clear process documentation, reduced variability in academic delivery, and enhanced satisfaction among students and faculty. DMAIC's iterative approach encourages continuous feedback loops, enabling institutions to respond promptly to emerging challenges in pedagogy and administration. The methodology's adaptability ensures it can address both administrative and academic processes, making it highly relevant for NEP-aligned reforms. Consequently, Six Sigma and DMAIC provide a structured pathway for universities and colleges to achieve measurable improvements in educational quality, supporting India's vision of inclusive and outcome-oriented higher education.

Table 1: DMAIC Mapping with NEP 2020

DMAIC Phase	Academic Interpretation	NEP 2020 Alignment
Define	Identify gaps in learning outcomes	Clearly stated Program & Course Outcomes
Measure	Assess current student performance	Continuous & formative assessment
Analyze	Identify causes of poor outcomes	Evidence-based curriculum review
Improve	Implement pedagogical & curriculum changes	Experiential & learner-centric methods
Control	Sustain improvements	IQAC & accreditation mechanisms

4: Research Methodology:

The present study employs an applied, analytical, and quantitative research design to enhance undergraduate students' academic performance using the Six Sigma DMAIC framework aligned with NEP 2020. A before–after experimental approach was adopted to compare student outcomes

prior to and following the implementation of structured quality improvement strategies. A total of 200 undergraduate students were selected using convenient sampling. Primary data were collected from internal examination scores, while secondary data were derived from relevant literature on Six Sigma and educational quality improvement. The independent variables included structured Six Sigma interventions such as interactive teaching methods, continuous evaluation, attendance monitoring, and remedial academic support. The dependent variable was student academic performance measured through internal test scores.

Critical to Quality (CTQ) was defined as achieving a minimum score of 40 marks. Statistical tools including descriptive statistics, defect rate analysis, Pareto charts, Fishbone diagrams, and paired t-tests were applied to measure variability, identify root causes of performance gaps, and evaluate the effectiveness of interventions.

The DMAIC phases guided the entire methodology:

- **Define:** Identification of poor academic consistency and failure to meet CTQ.
- **Measure:** Establishment of baseline performance and defect proportion.
- **Analyze:** Root cause identification using Pareto and Fishbone tools.
- **Improve:** Implementation of targeted pedagogical and academic strategies.
- **Control:** Monitoring through statistical indicators to sustain improvements.

This methodology treats education as a measurable process, ensuring evidence-based, outcome-driven, and replicable improvement aligned with NEP 2020.

5. Results and Discussion

5.1 Define Phase

The Define phase established the core academic problem as inconsistent and unsatisfactory performance among undergraduate students. Institutional academic records revealed that a considerable proportion of learners failed to attain the minimum acceptable level of academic achievement. In accordance with Six Sigma principles, the Critical to Quality (CTQ) parameter was defined as scoring ≥ 40 marks, representing satisfactory learning and course outcome attainment.

The key objectives of this phase were:

- To increase the overall mean academic performance.
- To reduce variability in student scores.
- To minimize the number of defects (students scoring below CTQ).
- To identify systemic factors responsible for poor learning outcomes.

5.2 Measure Phase (Baseline Data before Improvement)

Table 2: Descriptive Statistics of scores (at baseline)

Number of Students	Mean Marks (μ_1)	S.D (σ_1)	Minimum	Maximum	Students <40	Defect Rate
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600	45.2	10.4	18	72	234	39%
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With reference table 2, the baseline measurement indicates that although the mean score (45.2) is marginally above the passing threshold, the large standard deviation (10.4) reflects significant dispersion and instability in academic performance. A defect rate of 39% suggests that nearly two out of every five students fail to meet the minimum quality requirement, confirming that the teaching–learning process is statistically incapable and inefficient.

5.3 Analyze Phase

Step 1: Pareto Analysis of Root Causes (n = 234 Defective Students)

Table 3: Distribution of Cause affecting learning process

Cause Category	No. of Students	Percentage (%)
Irregular Attendance	62	26.5
Lack of Practice & Revision	48	20.5
Ineffective Teaching Methods	41	17.5
Mental Stress / Anxiety	29	12.4
Poor Physical Health / Fatigue	18	7.7
Lack of Digital Access / Tech Issues	16	6.8
Financial Constraints	11	4.7
Family / Social Distractions	9	3.9
Total	234	100

Table 3, demonstrate the Pareto analysis demonstrates that academic and behavioral factors dominate performance defects. Attendance, revision habits, and teaching methods collectively account for 64.5% of learning failures. When mental stress and physical fatigue are included, the top five factors contribute to 84.6% of total defects, validating the Pareto principle in an educational setting.

Step 2: Fishbone (Cause-and-Effect) Analysis

A comprehensive Fishbone analysis was conducted to classify multifactorial contributors to poor academic performance.

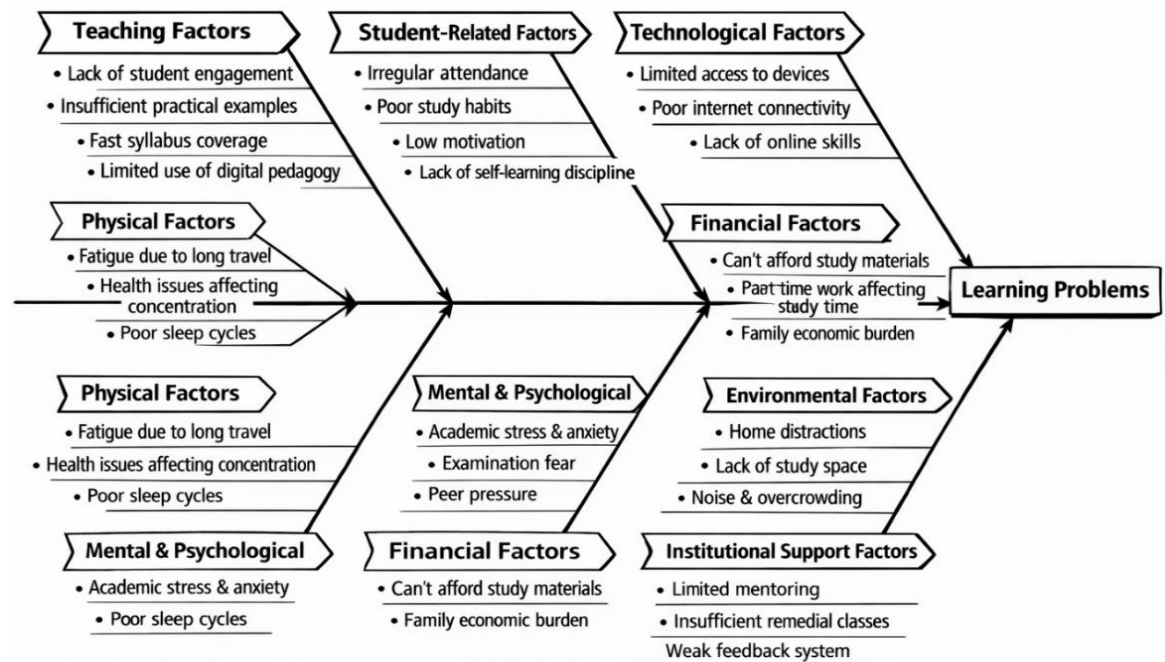


Fig.1: Fishbone (Cause-and-Effect) Analysis of learning problems

The analysis confirms that academic underperformance is the outcome of interconnected systemic deficiencies rather than isolated student failure. Educational quality gaps are driven by instructional, behavioral, psychological, economic, and technological barriers.

5.4 Improve Phase

Based on the comprehensive Fishbone (Cause-and-Effect) analysis, it was observed that learning deficiencies among students were not isolated but resulted from multiple interrelated academic, physical, psychological, technological, financial, environmental, and institutional factors. To address these systematically, a structured Six Sigma-based improvement strategy was implemented for a period of two months.

Targeted corrective actions were designed corresponding to each major cause category identified:

Table 4: Six Sigma-Based Improvement Strategies to Overcome Learning Problems

Category	Key Strategies
Teaching	Interactive pedagogy, examples, digital tools
Students	Attendance monitoring, study planning, revision
Physical	Health guidance, rest management, reduce fatigue
Mental	Mentoring, stress control, exam confidence
Technology	Device access, online materials, e-learning training
Financial	Scholarships, concessions, low-cost resources
Environment	Study space, library use, fewer distractions
Institutional	Remedial classes, mentoring, feedback

These corrective measures were implemented continuously for two months under the DMAIC Improve phase to minimize learning defects and enhance academic consistency.

Table 5: Post-Improvement Performance (After Two Months)

Students	Mean (μ_2)	S.D (σ_2)	Minimum	Maximum	Students <40	Defect Rate
600	56.8	7.2	35	78	54	9%

After two months of Six Sigma interventions, academic performance improved considerably. The mean score increased from 45.2 to 56.8, while variability decreased (SD: 10.4 to 7.2). Students below CTQ reduced from 234 to 54, lowering the defect rate from 39% to 9%.

$$\text{DPMO after improvement} = \frac{54}{600} \times 1,00,000 = 90,000$$

Table 6: Post-Improvement Performance (After Two Months)

Phase	Defect Rate	DPMO	Sigma Level
Before	39%	390,000	1.8 σ
After	9%	90,000	2.9 σ

5.5 Control Phase

The Control phase was strategically aligned with the quality assurance and learner-centric vision of NEP 2020 to ensure sustained academic improvement. All effective teaching and remedial practices were standardized and institutionalized in accordance with outcome-based education promoted under NEP. Continuous monitoring of student performance through periodic assessments supported NEP's emphasis on formative evaluation and competency tracking. Attendance audits and mentoring strengthened student engagement and accountability, reflecting NEP's focus on holistic and participatory learning. Feedback-driven teaching revisions ensured adaptive pedagogy, a key principle of NEP 2020. Technological integration and academic dashboards promoted data-based decision-making aligned with digital education reforms. Institutionalization through IQAC supported governance and quality benchmarking consistent with NEP's regulatory framework. Remedial and mentoring support reflected NEP's inclusiveness and equity in learning opportunities. Sustained improvement in mean performance and reduction in variability demonstrated enhanced learning effectiveness. The decline in defect rate confirmed better attainment of course outcomes. Improvement in Sigma level from 1.8 σ to 2.9 σ validated increased academic process capability. Overall, the Control phase operationalized NEP 2020's philosophy of continuous quality enhancement, accountability, and student-centered higher education

6. Six Sigma and NEP 2020

Overall, the study validates that Six Sigma is not merely a quality tool for industry but a powerful framework for implementing NEP-aligned reforms in higher education. By integrating structured

analytics, continuous improvement, and institutional control, Six Sigma strengthens the effectiveness, inclusiveness, and accountability of the teaching–learning ecosystem, thereby advancing the national vision of quality-driven higher education. The methodology can be widely applied for systematic curriculum alignment with Program and Course Outcomes, monitoring competency-based assessments, improving student retention and progression, enhancing blended and digital learning effectiveness, optimizing academic administration, and strengthening feedback-driven pedagogical reforms. Six Sigma also supports equitable learning by identifying at-risk students, minimizing performance variability, and enabling targeted remedial interventions. Its application in accreditation preparedness, institutional governance, and continuous academic audits further promotes NEP’s emphasis on transparency and accountability. Thus, Six Sigma provides a scalable and replicable model for effective NEP implementation and sustainable improvement in educational quality

7. Conclusions

The present study confirms that Six Sigma DMAIC is an effective and scientific framework for strengthening quality assurance in higher education and aligning learning outcomes with NEP 2020. By treating the teaching–learning process as measurable, the study systematically identified academic gaps and quantified performance deficiencies. The Define, Measure, and Analyze phases revealed that many students failed to meet the CTQ benchmark due to academic, behavioral, psychological, technological, and institutional factors. The Improve phase implemented learner-centered teaching, continuous assessment, mentoring, remedial support, digital inclusion, and attendance control. These interventions significantly enhanced academic performance and reduced variability. The defect rate declined from 39% to 9%, showing strong process improvement. The Sigma level improved from 1.8σ to 2.9σ , confirming enhanced academic process capability. The Control phase institutionalized dashboards, feedback-based teaching, remedial tracking, and IQAC supervision to sustain gains. These sustained improvements reflect NEP 2020’s emphasis on outcome-based and continuous evaluation. Overall, Six Sigma DMAIC provides a replicable and data-driven model for advancing academic quality and accountability in higher education.

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