Chapter 1

Use of Six Sigma and Lean Six Sigma Methodologies in Higher Education Institutions: A Systematic Review*

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1.1 Introduction

Quality has always been important in higher education (HE), but ever-increasing demands of stakeholders and a competitive environment have made it further gain significance. This changing scenario has made it essential for higher education institutions (HEIs) to adopt quality improvement methodologies to create unique value for their students and offer better services. The Six Sigma and Lean Six Sigma (LSS) models, which are the most commonly used quality improvement methodologies in the

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manufacturing industry, are now also being utilised by HEIs to improve quality. Six Sigma is a customer-focused model that helps drive remarkable improvements in processes with sustainable consequences and improved customer satisfaction (Bin, 2015). LSS is the integration of the Lean and Six Sigma philosophies (Sheridan, 2000), which can result in more rapid and effective improvements in performance than using Lean and Six Sigma as separate strategies (George, 2003). In HE, Six Sigma can solve complex problems in the education system and the Lean approach can reduce waste in the process (Mukhopadhyay, 2017).

Various studies have described the use of Six Sigma and LSS methodologies by HEIs to improve their quality of education. In addition, Hess and Benjamin (2015) have highlighted that LSS can be applied within university settings to improve processes in curriculum delivery, business and auxiliary services, admission, enrollment management, and research. Further, Antony *et al.* (2018) found that several LSS projects were executed across administration, finance, human resources (HR), information and technology (IT), and library services, except academic processes of a HEI. The authors suggested that the use of LSS should be prioritised in the academic process of HEIs such as in marking and curriculum development as well as for providing high-quality teaching and delivering innovative teaching methods.

In the recent past, promoting the quality of teaching and learning has gained significant importance among policy makers of HEIs to enhance students' satisfaction and to meet the criteria of accreditation and ranking agencies. As a consequence, HEIs actively explore various real, apparent, and measurable methods to improve the quality of teaching and learning (McCormick, 2009). Therefore, this study aims to perform a literature review of Six Sigma and LSS methodologies in teaching and learning processes of HEIs to address how these methodologies are implemented in HEIs and their corresponding improvements in academic processes.

1.2 Methods

1.2.1 Search strategy

Relevant studies were identified through an electronic literature search in the following databases: Web of Science, Science Direct, Pro Quest,

Fig. 1.1. Identification and Selection Process of the Studies.

Scopus, and Google Scholar. The search was restricted to original articles that focused on the application of Six Sigma and LSS methodologies in teaching and learning processes in HE and were published between the years 2000 and 2018. The search was carried out using the following keywords: ‘six sigma’, ‘lean six sigma’, ‘higher education’, ‘universities’, ‘higher education institutions’, and ‘teaching and learning’. The identification and selection process of the studies is detailed in Fig. 1.1. In total, 22 articles met the inclusion criteria and another four relevant articles were included from the references of the included studies. Therefore, 26 articles were eventually included and reviewed for data extraction.

1.2.2 Data extraction

This study reviewed all included articles for details pertaining to their research methodology; country-and year-wise distribution of publication; authorship; type of methodology, tools, and techniques used for process improvement; and primary findings.

1.2.3 *Results*

The primary findings of each study is described in Table 1.1.

Table 1.1. Details of the 26 Articles Included for Analysis.

Authors	Findings
Hargrove and Burge (2002)	Six Sigma was found to be useful for increasing student retention rates and redesigning the process.
Perry (2004)	The instructors can use feedback from control charts to monitor their teaching effectiveness and plan for further improvement.
Emiliani (2005)	Kaizen team formed for each of 10 courses of a postgraduate management program successfully identified problems related to the process and the improvement opportunities.
Holmes <i>et al.</i> (2005)	Six Sigma Define, Measure, Analyze, Improve and Control (DMAIC) methods can be applied in Information systems (IS) program to design and implement its program and curriculum student learning objectives.
Kukreja <i>et al.</i> (2009)	Following Six Sigma implementation, the students' performance improved to 47.3, above the desired goal of 46.5.
Chen and Kirby (2010)	Taguchi parameter design (TPD) is more effective than the classical design of experiments (DOE) in a learning environment.
Jaraiedi <i>et al.</i> (2010)	First-term grade point average (GPA) was predicted to be an important factor affecting first-year retention and its improvement using appropriate strategies should be prioritised.
Kaushik and Khanduja (2010)	Student passing rate increased with the improvement of sigma level from 2.28 to 4.17.
Kanakana <i>et al.</i> (2012)	Following improvement actions, students test average improved from 49% to 67%. Also, the throughput rate of the observed subject moved from 38% to 71%.
Prasad <i>et al.</i> (2012)	Potential quality characteristics responsible for 80% of failure of students were revealed using Pareto diagram and highlighted the need for more attention to achieve Six Sigma quality in engineering education.
Yu and Ueng (2012)	Using teaching effectiveness analysis matrix (TEAM), attributes that are out of teaching capability zone were identified. Based on this, feasible improvement actions can be developed through brainstorming sessions.
Antony <i>et al.</i> (2014)	Using DOE, the instructor can understand factors influencing students' satisfaction scores during the delivery of teaching.
Vijay (2013)	Poisson distribution model was applied to rate the students' opinion about the teaching and learning elements of a HE institution using a six-point quality rating scale.

(Continued)

Table 1.1. (Continued)

Authors	Findings
Chow and Downing (2014)	Attrition rate between cohorts reduced by 2.5% through improved student-retention process and net tuition and fees revenue from additional students were retained.
Mazumder (2014)	Factors affecting the quality of education process and student performance or inputs were identified. GPA of two courses were out of process control and need for improvement.
Pavlovic <i>et al.</i> (2014)	Students' pass rate in exams increased following LSS DMAIC methods.
Babajide and Moore (2015)	Design for Six Sigma (DFSS) can help students to organise and communicate their findings in a systematic way.
Bargerstock and Richards (2015)	Time for completion of close-the-loop (CTL) report reduced from 45 minutes to 10–15 minutes and faculty compliance rate on CTL report submissions improved from 10% to 47%.
Narula and Grover (2015)	Student passing ratio improved by 8.45% from 49.67%.
Tetteh (2015)	Leadership attributes of the teacher vital for improving the learning outcome were revealed using the Kano model.
Vasanth <i>et al.</i> (2015)	Six Sigma DMAIC methods can be used to improve the internet connectivity through a set of procedures in an effective way.
Lacher and Staudacher (2016)	LSS using DMAIC methods can be used to reduce student dropouts from HEIs.
Matorera and Fraser (2016)	Using Six Sigma roadmap with quality function deployment (QFD) can optimise the transformation of stakeholder needs into organisational strategies, products and service quality.
Thomas <i>et al.</i> (2017)	The development and application of the LSS framework aided the curriculum development team to broadly apply LSS in the HE sector. The Shainin key variables search technique (KVST) assisted the team to prioritise the key variables with regard of importance, and thus allowed them to apply the appropriate tools and techniques within the LSS framework to achieve maximum performance.
Antony <i>et al.</i> (2018)	LSS projects were done across administrative, finance, HR, IT, and library services, but no projects were done for improving academic processes such as teaching effectiveness.
Gupta <i>et al.</i> (2018)	The study found that LSS (DMAIC) methodology can be used to overcome identified barriers in drop out reduction program.

1.2.4 *Country-wise article distribution*

The 26 articles were published from eight different countries, with wide geographical distribution. About 58% of articles were published from USA and UK, 19% were from India, and the remaining 23% were from Italy, Serbia, Taiwan, Ghana, and South Africa (Fig. 1.2).

1.2.5 *Year-wise article distribution*

Between 2000 and 2009, only 1–2 articles were published each year on the use Six Sigma and LSS in HEIs. However, this increased to >3 articles/year between 2010 and 2015, except in 2013, and then again decreased to 1–2 articles/year from 2016 to 2018 (Fig. 1.3).

1.2.6 *Authorship*

About 39% of the 26 articles had two authors, while 19%, 27%, and 15% had one, three, and four or more authors, respectively. Notably, international collaboration in authorship was found in only two of the 26 studies. Expectedly, all the authors were academicians from various universities.

Fig. 1.2. Countries of Article Publication (as per First Author Affiliations).

Fig. 1.3. Year-Wise Distribution of the 26 Articles.

1.2.6.1 Research methodology adopted

About 50% of the studies were exploratory in nature, while 42% were case studies. Only 8% of the studies were conceptual or descriptive, and thus described the application of Six Sigma methodology in HE.

1.2.7 Distribution of methodology used for process improvement

The majority of the studies ($n = 18$) utilised the Six Sigma methodology. Of these, 11 studies adopted the DMAIC methodology, one study used both the DMAIC and DFSS methodologies, one study adopted the DFSS methodology, and two studies adopted the DOE methodology. Of the eight studies that utilised the LSS methodology, four used the DMAIC methodology.

1.2.7.1 Tools and techniques used

Seven quality control tools were most commonly used, namely, Pareto chart, control charts, histogram, run chart, and Ishikawa/fishbone/

cause-and-effect diagram. In case of control charts, individual (IX) chart, moving range (mR) chart, X-bar/S chart, and P chart were used in the included studies. Three studies used Poisson distribution in the HE settings. The other Six Sigma tools found to be used were process flow-charts (n = 1), process mapping (n = 1), failure mode and effects analysis (FMEA) (n = 4), QFD (n = 2), Kano model (n = 2), process capability analysis (n = 4), and tree analysis (n = 1). Six Sigma techniques such as brainstorming sessions, benchmarking, cost-effectiveness analysis, and box plots were used. In LSS studies, lean tools such as waste, value stream mapping, 5S, Poka-yoke, and Kaizen were used along with Six Sigma tools in the HE environment.

1.3 Discussion

This systematic review included articles that utilised Six Sigma and LSS methodologies for teaching and learning processes in HEIs.

1.3.1 *Application of the Six Sigma and LSS methodologies in teaching and learning*

In HE, students are the customers and direct users of the education services, and thus their satisfaction is required in all teaching and learning processes to ensure quality in HE (Yeap, 2008; Vijay, 2013; Al Kuwaiti and Subbarayalu, 2015). In addition, learning outcomes and teaching effectiveness are recognised as key indicators of quality in HE. Therefore, instructors should possess skills to develop and assess students' learning outcomes (Bahous and Nabhani, 2015; Chahine and Khan, 2015) as well as utilise students' feedback to improve their quality of teaching (Hejase *et al.*, 2015). In addition, students' learning experience and outcomes are highly influenced by the learning environment prevailing in HEIs. There is a positive relationship between the students' perceptions toward learning environment and their academic performance (Ahmed *et al.*, 2018). Moreover, student failures, dropouts, and retention are considered as non-conformance in terms of quality management of teaching and learning process. Enhanced student learning through a quality

improvement model would result in reduction of their failure rates and in successful completion of their courses on time. Finally, effective teaching might result in quality learning for students, which in turn creates qualified students and improves customer satisfaction in HE (Yeap, 2008).

1.3.2 Instructional effectiveness

Holmes *et al.* (2005) stated that the Six Sigma methodology can be utilised for program design, curriculum development, classroom instruction, and student learning assessment to improve the teaching function in HEIs. To reveal the instructional effectiveness, the data on course assessment form we reanalysed using control chart and identified the 'out of control' points. Fishbone diagram was also used to find the potential causes for those 'out of control' points. These tools provide feedback to the instructor to improve their teaching effectiveness before completion of the course (Perry, 2004). Likewise, a feedback system was established using DMAIC to monitor the outcomes of teaching evaluations in HEIs. This system would prove valuable to HEIs in strengthening teaching quality within a competitive environment (Yu and Ueng, 2012). Subsequently, Vijay (2013) applied the Poisson distribution to rate the students' feedback on teaching and evaluation methods adopted by instructors, and their teaching effectiveness using a six-point quality rating system. Further, there has been a clear misconception that DOE is primarily applied in the manufacturing process. However, Antony *et al.* (2014) utilised DOE to understand factors that influence the students' satisfaction scores during the delivery of teaching. In that study, the author applied DOE to one module with a small sample size, but recommended it for further studies with more number of modules in a program. In another study, leadership attributes of the teacher required for improving the learning outcome were revealed using the Kano model (Tetteh, 2015).

Barger stock and Richards (2015) enhanced the CTL process for effective monitoring of course delivery in a business school using the LSS DMAIC methodology. Such process improvement decreases cycle time, eliminates on-value added steps, increases customer value, and improves faculty compliance rates.

A recent study by Antony *et al.* (2018) explored how an HEI has involved in its LSS journey as a process excellence methodology to improve their core and supporting business processes. In this study, several LSS projects were executed across administration, finance, HR, IT, and library services of the HEI. However, no projects were undertaken to improve academic processes such as teaching effectiveness. The authors suggested selecting and prioritising LSS projects within academic processes such as in marking and curriculum development by academics as well as for providing high-quality teaching and delivering innovative teaching methods.

1.3.3 *Students' performance*

For students' performance, Mazumder (2014) adopted the Six Sigma DMAIC methodology and demonstrated the use of tools such as process map with supplier, input, process, output and customer (SIPOC), fishbone diagram, FMEA, and control charts for improving quality in HE. The author identified factors influencing the quality of educational processes and student performance such as GPA, teacher's performance, and number of students. In a study by Kanakana *et al.* (2012), it was found that students spend lesser time in regular classes than during test weeks in subjects that reported low throughput rate using the LSS DMAIC methodology. Few studies have observed that improvement of student passing rate in HEIs is achievable using the Six Sigma DMAIC methodology (Kaushik and Khanduja, 2010; Narula and Grover, 2015).

Pavlovic *et al.* (2014) applied the LSS methodology and identified various basic types of waste in the educational process. Pareto analysis was used to assess engineering courses that were critical for passing exams, following which the causes for lower number of passed exams were identified using fishbone diagram and an appropriate improvement plan was implemented. In addition, five quality characteristics such as motivated instructors, advanced communication facilities, university–industry partnerships, chances for knowledge enhancement, and modern learning resources were found to be responsible for the higher occurrence of failure of students in an engineering institution using the Pareto diagram. It is essential to concentrate on these characteristics to achieve quality education in the respective institution (Prasad *et al.*, 2012).

In another study, Kukreja *et al.* (2009) showed an improvement in business students' performance using the Six Sigma methodology. However, these improvements could not be sustained in the subsequent years. Various studies have also used Six Sigma tools such as Kaizen, QFD, and Six Sigma roadmaps in business school programs (Emiliani, 2005; Matorera and Fraser, 2016).

1.3.4 Student retention

Hargrove and Burge (2002) described the use of Six Sigma DMAIC methodology for improving student retention in an engineering program. The sigma value using Poisson distribution and the rolled throughput yield for the process were calculated. A student-survey Pareto chart was used to rank factors influencing students' retention. Another model, DFSS, was suggested for redesigning the engineering curriculum to ensure the success of Six Sigma. Additionally, a simple QFD matrix was developed using several student surveys on the curriculum to identify student requirements. This matrix helped determine factors affecting students' performance and retention. Recently, studies have also assessed factors influencing student dropouts and suggested using the LSS DMAIC methodology to overcome barriers in dropout reduction strategies (Lacher and Staudacher, 2016; Gupta *et al.*, 2018). In the study by Jaraiedi *et al.* (2010), first-year retention rate in an engineering college improved after the Six Sigma DMAIC methodology was utilised. Likewise, a reduction of the attrition rate was also observed using the Six Sigma DMAIC methodology, wherein sigma tools such as P chart, process capability analysis, chi-square, and regression were used. Improved student retention rate results in additional revenue to HEIs and likely helps meet demands for a qualified workforce (Chow and Downing, 2014).

1.3.5 Learning environment

Chen and Kirby (2010) found that TPD is more effective than classical DOE in a learning environment among the students who enrolled in an advanced manufacturing concepts course of a university. Moreover, Six Sigma DMAIC methodology can be used to reduce the defects in the internet connectivity, thereby improving blended learning (e-learning),

and student's performance in an academic institution (Vasanth *et al.*, 2015). In addition, Babajide and Moore (2015) reported that the DFSS methodology can serve as a learning tool in university–industry problem-based learning environments in HEIs. This methodology can be used by students to organise and communicate their ideas in a systematic way when working on their projects.

1.3.6 Curriculum development

Thomas *et al.* (2017) gathered information from practitioners through a survey regarding key strategies, systems, tools, and techniques being used in HEIs, and found that the systematic, extensive use of LSS was less. In general, the Lean methodology was observed as the strategy of choice in HEIs. There was very little evidence of advanced Lean/LSS tools being used, and the most commonly used tools in HEIs were value stream mapping, 5S, cause-and-effect analysis, Pareto, and SIPOC. Later, the researchers proposed and implemented the LSS framework, which incorporated Lean tools and DMAIC in the university. This framework assisted the curriculum development team to broadly apply the LSS framework within the university. In addition, KVST was used to prioritise key variables and apply appropriate tools and techniques within the LSS framework to attain maximum performance. The LSS framework and application of KVST demonstrated that LSS can be effectively applied in critical areas of HEIs such as curriculum development and enhancement.

Although many studies demonstrated the application of Six Sigma and LSS methodologies in teaching and learning processes in HEIs, some have highlighted that the lack of LSS projects in academic processes and a limited use of Lean/LSS tools in HEIs (Thomas *et al.*, 2017; Antony *et al.*, 2018). To overcome this, HEIs should be aware of the challenges, critical success factors (CSFs), tools and techniques used, and key lesson learned for the implementation of LSS in HEIs.

1.3.7 Challenges in implementing LSS in HE

Several researchers have listed the various challenges and barriers in implementing LSS in HE (Antony *et al.*, 2012; Antony, 2015; Antony and

Cudney, 2016; Antony *et al.*, 2018). The main challenges encountered are problems adopting terminologies from the manufacturing industry to the HE sector; lack of leadership to drive LSS effectively; difficulty in defining voice of customers; poor understanding of strategy for achieving leanness by policy makers of HEIs; lack of commitment and support from policy makers of HEIs; lack of staff engagement in the execution of projects; existing culture in the HE sector; poor communication across HEIs due to a silo mentality across departments and faculties; lack of systems thinking principles across the sector; viewing the lean initiative as a quick fix; improvement in curriculum development; quantifying the impact of attributes such as the instructors' personality traits and teaching methods; making schemes and methods; and teaching effectiveness.

1.3.8 CSFs for introduction of LSS in HEIs

CSFs of LSS in HE sector include uncompromising top management support and commitment; strategic and visionary leadership; developing organisational readiness; organisational culture; resources and skills to facilitate implementation; project selection and prioritisation; and effective communication at all levels (Antony *et al.*, 2012; Antony and Cudney, 2016; Antony *et al.*, 2018). Antony (2014) also revealed the following key readiness factors for the successful implementation and sustainability of LSS in the HE context: leadership and vision, linking LSS to university's strategy, customer focus, and selecting the correct people. In addition, Kim (2010) observed that managers' roles are very essential, as Six Sigma pursues top-down management. It is revealed that mental discipline is also a CSF that allows an organisation to realise its vision through the fundamentals of Six Sigma activities.

1.3.9 Tools and techniques used in HEIs

It is essential to understand that the tools and techniques used in successful implementation of LSS in HE settings. Many organisations consider when to apply tools or techniques and how to apply them to overcome under certain situations. This yields significant long-term benefits. The selection of LSS tools and techniques depend on the needs of the

organisation. The most relevant tools and techniques suggested to HEIs are process mapping/value stream mapping, cause-and-effect analysis, visual management, Pareto analysis, project charter, SIPOC, and rapid improvement workshops (Antony *et al.*, 2012).

1.3.10 Key lessons learned from the execution of LSS projects in HEIs

Few studies have explained the key lessons learned from the implementation of LSS projects across HEIs (Antony and Cudney, 2016; Antony *et al.*, 2018). Those lessons include (i) appropriate data are not readily available in the HE sector; (ii) identification of CTQs is very problematic; (iii) terminologies taken from manufacturing industries are not readily accepted in the HE sector; (iv) people are uncomfortable using more data-driven and statistical tools and techniques; (v) quantifying process improvement savings is extremely difficult without a recognised framework within the higher education; (vi) process improvement should consider the whole system if it is to be effective across any organisation; (vii) there is need of culture of openness, trust, and acceptance in the HE sector; (viii) most projects done by staff members were at an operational level, and thus there is need for more challenging strategic projects that are aligned with the goals of the university; (ix) absence of a LSS deployment champion at the university level caused a number of issues; and (x) the university should consider the formal reward or incentive system to encourage staff engagement and participation.

Such information on the challenges, CSFs and key lessons learned would aid the policy makers and faculty members of HEIs to execute more LSS projects in the academic processes such as teaching, learning, and curriculum delivery, as well as in other processes related to admission, finance, HR, and research.

1.4 Conclusions

Use of Six Sigma and LSS methodology in the HE environment resulted in marked changes in teaching and learning process such as course assessment, students' feedback, passing rate, performance, and retention.

DMAIC was the most commonly adopted methodology in the HE section, but DOE and DFSS methods have also been used. Six Sigma tools have also helped determine critical areas in teaching and learning process. These tools help determine the reasons for the low course assessment scores as well as students' failure, retention, and dissatisfaction, which in turn assists in developing necessary actions. This study highlighted the challenges, CSFs, and key lessons learned from the implementation of LSS in HE environments. This would aid policy makers to frame appropriate strategies to overcome the challenges as well as to consider the CSFs and key lessons learned while implementing LSS implementation in the HE sector.

1.5 Limitations and Practical Implications for Further Research

This study is limited its focus on teaching and learning and it can be extended to administrative and research functions of HEIs in the future. In addition, student-oriented features such as program evaluation, learning outcomes, student experience, facilities, and training programs can also be addressed in future studies. Most studies in the literature are focused on students' problems rather than that of faculties. However, faculty issues such as research productivity; attrition; job satisfaction; lecturing skills; training and development; delay in evaluation process; and compliance rate for submissions of program and course specifications and course report can also be studied. In addition, this study is only restricted to original articles; in future studies, various conference papers published in the American Society for Engineering Education database can also be included. This systematic review would aid stakeholders of HEIs to enrich their knowledge regarding the use of Six Sigma and LSS methodology in HEIs and help them make further progress in the implementation of these methodologies to improve quality in HE.

1.6 Summary

HEIs are in need to assure a standard quality of services to sustain in the market they operate in. Hence, these institutions commenced to adapt

quality improvement methods such as Six Sigma and LSS to improve and sustain the quality in various processes in HE. This study aimed to provide an understanding regarding the use of Six Sigma and LSS methodologies by HEIs to improve their quality of HE. A systematic review was conducted using Web of Science, Science Direct, Pro Quest, Scopus, and Google Scholar. Original articles that focused on the application of Six Sigma and LSS methodologies in the teaching and learning processes of HEIs and that were published between 2000 and 2018 were included in this study. A total of 26 relevant articles were found, and their research methodology; type of methodology, tools and techniques used for process improvement; authorship; and country- and year-wise distribution were analysed. This study discusses changes resulting from the implementation of the Six Sigma and LSS methodologies, especially in the teaching and learning processes. In HE environment, these methodologies were found to be successfully applied for course assessment, student feedback, passing rate, performance, and retention. This study also discusses the various challenges, CSFs, and key lessons learned for the implementation of LSS in HE environments. Findings of this study would enhance the knowledge of policy makers and faculty members regarding the use of Six Sigma and LSS methodology in HEIs and guide its implementation in academic processes such as teaching effectiveness to improve quality in HE.

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