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Real-World Application: Six Sigma Quality Tools for Continuous Performance Improvement in Specific Educational Practices - A Systematic Review

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Abstract. The education sector is continuously seeking new approaches to improve the existing educational process while reducing instances of failure. Recently, the use of Six Sigma quality tools as a continuous improvement tool has proven to be a promising solution. To investigate the effectiveness of this method, a systematic literature review was conducted to summarize relevant empirical data on Six Sigma quality tools in education. This systematic review follows the PRISMA criteria (preferred reporting items for systematic reviews and meta-analysis) and utilizes three major databases: Web of Science (WoS), Scopus, and Dimensions. Eleven articles met the given criteria, and the empirical results revealed that Six Sigma quality tools – including Suppliers, Inputs, Process, Outputs and Customers (SIPOC), Pareto analysis, Fish Bone technique, Failure Mode and Effect Analysis (FMEA), and Statistical Process Control (SPC) – could be used in institutions to meet practitioners' requirements and achieve the desired quality standards. This study will provide a more comprehensive understanding of the benefits of Six Sigma quality tools in education as well as the ways in which they can be used to improve educational quality for students. Six Sigma quality tools are an innovative and promising approach to improving education. As indicated by the findings, further research is recommended to assess the use of the Six Sigma quality tools in evaluating educational interventions in various educational settings, especially at the school level, in order to verify significant improvements in educational quality and, ultimately, better student outcomes.

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1. Introduction

Recently, Six Sigma quality tools have been used to raise the quality of education by making data-driven improvements through statistical analysis. Quality education is necessary for development around the world (Sandu & Sharma, 2020). Education also plays a vital role in creating quality human capital and contributes to a country's development (Bumjaid & Malik, 2019; Pal, 2022). One of the measures for improving the quality of education provided in institutions is to ensure that the standard of education reaches favourable standard compared to countries with excellent education systems (Jayakumar et al., 2017). In general, quality in education is perceived as an assessment of the educational process to achieve the set standard (Bumjaid & Malik, 2019; Dian et al., 2022) and to focus on the needs of the customers of educational institutions; namely, students, parents, and employers (Shoeibi & Zahmatdoost, 2018). In essence, students are the customers of educational institutions, while the learning outcomes achieved by students represent a service provided by educational institutions. Furthermore, students can also be viewed as products that will be sold by educational institutions to employers in the future (Mazumder, 2014; Milosavljevic et al., 2018).

Over the past few years, the field of education has faced various challenges that require urgent attention and mitigation efforts (Nadeau, 2017; Pal & Ghosh, 2022). Many factors affect the quality of education, such as changes in education policies themselves, i.e. curriculum, infrastructure facilities, management, leadership, and teaching and learning (Dian et al., 2022). However, the quality of education in a country is not dependent solely on the policies but requires all stakeholders, especially teachers, to improve their performance (Kaplani & Zafiropoulos, 2022; OECD, 2015). Teacher performance or effectiveness is considered a critical factor for development and improvement, especially in developing a new vision for an education system (Almutairi & Shraid, 2021). As a result, collaboration between educators and stakeholders is essential to create a quality education system that successfully produces effective and productive citizens (Sabtu et al., 2023). Accordingly, monitoring, evaluation, and improvement in the planning cycle will continue to play an important role in moving a country's education system forward.

Thus, continuous improvement is needed to ensure that the quality of education meets the standards set by education policymakers. Many continuous improvement models, approaches, and tools have been implemented in educational institutions to ensure that the quality of education is improved and maintained (Taraza et al., 2023; Xin et al., 2021). Various standard improvement tools are used in educational institutions, such as Total Quality Management (TQM) (Sohel-Uz-Zaman & Anjalin, 2016; Tresnasari et al., 2020), Kaizen (Kolodziejczak et al., 2019; Susana et al., 2021), Six Sigma (Sandu & Sharma 2020; Wang 2022), Lean Six Sigma (Shanshan et al., 2022; Xin et al., 2021) and Balanced Scorecard (Camilleri, 2021; Cheowsuwan, 2016). However, the careful selection of

continuous improvement tools should be emphasized for meeting the specific goals of each educational institution to ensure that it can appropriately adapt the approach used to suit its own policies, culture, and challenges in order to improve educational quality.

Six Sigma has been successfully implemented in many sectors as a tool for evaluating quality performance. Originally, the Six Sigma approach was introduced by Motorola to improve products and maintain the quality of services offered (Costa et al., 2021; Montgomery, 2019). Due to its outstanding success, many large companies have become interested in using Six Sigma as a business improvement strategy to increase profits while overcoming competitive threats (Lu et al., 2017). The Six Sigma approach focuses on planning and implementing measurement-based improvement strategies to reduce defects and variation in the production of products or services (Davis & Fifolt, 2018; Hariharan.R, 2015). Therefore, the Six Sigma approach has been successfully implemented in the field of industry and manufacturing (Abdulla & Kavilal, 2022; Smętkowska & Mrugalska, 2018). As a result, the central concept of Six Sigma has attracted the attention of organizations across all sectors.

Not only is the Six Sigma approach applicable to business industries, but it can also be an effective and efficient strategy for improving the quality of education. This has been demonstrated, as the Six Sigma approach has been developed and used as a practical approach to enhancing the quality of education around the world (Kremcheeva & Kremcheev, 2019; Pal & Ghosh, 2022). In addition, most countries have used elements of Six Sigma in their educational systems (Cudney et al., 2014, 2018). Educational areas in which the Six Sigma DMAIC has been used include management (Laux et al., 2017; MacIel-Monteon et al., 2020), teaching and learning (Wang, 2022; Yu & Ueng, 2012), and improving student performance (Abdulla & Kavilal, 2022; Elfanda, 2021).

The Six Sigma approach is popular as it provides structured improvement strategies to meet customer requirements (Cudney et al., 2014) by improving processes using the Six Sigma DMAIC (Define, Measure, Analyze, Improve, Control) or the Six Sigma DMADV (Define, Measure, Analyze, Design, Verify) (Elfanda, 2021; Tjahjono et al., 2012; Xin et al., 2021). DMAIC and DMADV focus on reducing process changes and defects in processes to 3.4 or fewer per million opportunities (DPMO) to increase customer satisfaction (Montgomery, 2019). This means that to achieve Six Sigma levels, the probability of producing a defect is only 3.4 per 1,000,000 units, and 99.99966% of the results are perfect (Montgomery, 2019). The process is so accurate and precise that it can achieve six standard deviations between average performance and the specification limit set by the customer.

In theory, the difference between the Six Sigma DMAIC and Six Sigma DMADV models is that DMAIC aims to improve existing processes. On the other hand, DMADV is used to create new products or develop methods from scratch (Elfanda, 2021). In other words, the Six Sigma DMAIC model is an improvement process for existing processes that are operating below specifications and in need

of additional improvements (Costa et al., 2021), while the Six Sigma DMADV model is used for developing a new strategy or product (Hariharan 2015). However, in educational institutions, the process implementation cannot be specified from the beginning because there are procedures and standards in academic institutions that have been set by policymakers and must be followed. Therefore, the Six Sigma DMAIC is better placed to improve and enhance quality in educational institutions (Elfanda, 2021; Kremcheeva & Kremcheev, 2019; Shinta Rizki et al., 2021; Shoeibi & Zahmatdoost, 2018).

The main goal of implementing the Six Sigma DMAIC in education focuses on customers' needs (Hariharan 2015). Prior studies in the literature reveal that the Six Sigma DMAIC model has been used as an improvement and quality improvement strategy in various areas of education (Cudney et al. 2014; Kremcheeva & Kremcheev 2019; LeMahieu et al. 2017; Pal & Ghosh 2022). These efforts begin in the first phase of identifying the problem and the goal to be achieved, while determining what the customer needs in the educational institution to plan the strategy (Bumjaid & Malik, 2019; Wang, 2022). In addition, the second measurement phase involves collecting and analyzing data on the problems identified in the first phase (Abdulla et al., 2020; Cano et al., 2016). In the third phase, the collected data are analyzed to obtain accurate information regarding issues related to the quality of the education (Bumjaid & Malik, 2019; Wang, 2022). Next, the fourth phase is the improvement step and focuses on solving the problems found. Finally, the last phase is control. In this step, measures are taken to ensure that errors are not repeated and that the proposed improvements follow the results of the Six Sigma analysis (Bumjaid & Malik, 2019; Cano et al., 2016).

As a tool for assuring quality education, Six Sigma is a continuous improvement methodology that uses statistical methods and various quality tools (Shoeibi & Zahmatdoost, 2018). Quality tools are tools or techniques used in the quality control process to ensure that the product or service achieves the desired quality standards. Put simply, process improvement using the Six Sigma approach will employ quality tools in achieving quality improvement (Tjahjono et al., 2012). Previous studies have shown that standard quality tools assist in data collection and consolidation, problem definition or resolution, flow analysis, and process flow diagram creation. Standard quality tools include check sheets, Pareto charts, cause-and-effect diagrams, scatter plots, histograms, and statistical process control (Jayakumar et al., 2017).

Despite its high potential for transforming the quality of education, the use of Six Sigma quality tools varies in the field of education. Using the right quality tools can help improve quality, reduce costs, and increase customer satisfaction. In addition to reducing activities that do not add value, the Six Sigma quality tools can increase the quality of education. However, the selection and use of quality tools depend on the challenges that need addressing, in order to achieve successful results (Tjahjono et al., 2012). Therefore, selecting quality tools is based on the identified needs or purposes and ensures that the options are suitable and appropriate.

Jayakumar et al. (2017) also explained the importance of using quality tools, such as Six Sigma; the explained that this helps in ensuring improvement in educational institutions by identifying problems that arise, addressing deficiencies that are identified, and recommending improvement actions to achieve the desired quality goals. In addition, this tool helps to improve the quality of educational institutions, anticipate potential problems that will occur, and address the deficiency before it worsens (Jayakumar et al., 2017; Mazumder, 2014). As a result, all decisions for improvement will be based on data analysis rather than intuition or guesswork regarding the best actions to take (Abdulla et al., 2020; MacIel-Monteon et al., 2020).

In summary, using Six Sigma quality tools in education can help improve the quality of education while meeting customer requirements, thereby increasing efficiency, improving administrative processes, and raising the standard of educational institutions. Based on the explanation of the important contributions of Six Sigma and findings from previous research, the purposes of this systematic study are as follows:

1) To determine when and where research has been conducted on improving educational quality using Six Sigma quality tools;
2) To explore evidence of the Six Sigma quality tool for improving educational quality; and
3) To determine which Six Sigma quality tools are generally used for quality improvement in education.

2. Methodology

The systematic literature review (SLR) refers to an analysis of the studies that have been conducted to answer research questions by identifying, analyzing, formulating, and critically evaluating the content in relevant previous studies. This SLR used the preferred reporting elements for systematic reviews and meta-analyses (PRISMA) method. The preparation of articles using the PRISMA method includes the following four phases: identification, screening, eligibility, and inclusion. To begin the assessment research, the first step was to create research questions and collect relevant articles. Data collection and analysis are organized as follows:

2.1 The Review Protocol (PRISMA)

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart guidelines are used as a checklist for selecting articles appropriate for the research question (Moher et al., 2009). Page et al. (2021) stated that PRISMA is a quality guideline for highlighting literature because it provides a relatively rigorous and detailed process to ensure the consistency and quality of the review process. Okoli (2015) stated that one of the advantages of the PRISMA method in social sciences is that the papers obtained are from high-quality data sources and are recognized by all researchers. There are four steps in the PRISMA flowchart to determine which study is appropriate for the researcher's needs, beginning with the identification process, screening, eligibility, and inclusion (Gillath & Karantzas, 2019; Mohamed et al., 2020; Moher et al., 2015).

2.2 Resources

Three academic databases were used when searching for articles on SLR: Web of Science (WoS), Scopus, and Dimensions. Previous studies have stated that WoS and Scopus are recognized as the central bibliographic databases (Pranckute, 2021; Singh et al., 2021). Meanwhile, Gusenbauer and Haddaway (2020) found that WoS and Scopus are among the most helpful "search engines" for finding relevant and high-quality articles for SLR. Therefore, WoS and Scopus were used as primary databases. There is a new academic data rank called Dimensions, which is gaining recognition. A study by Singh et al. (2021) found that nearly 96% of journals in WoS are also indexed in Scopus and Dimensions. Additionally, Thelwall (2018) also suggests that Dimensions is a unified database for article searching and can be used as an alternative to Scopus or WoS for research evaluation.

2.3 Systematic Review Process

The most crucial step in conducting a systematic review is to establish a plan and guidelines to ensure that the study can be performed regularly. Planning a systematic review begins with listing the requirements, setting objectives and research questions, and creating a systematic review protocol to avoid bias in the study. The process of systematic search strategies has four major phases: Identification, Screening, Eligibility, and Inclusion. The PRISMA flow diagram by Page et al. (2021) is presented in Figure 1 shows to explain the process of searching and screening articles for analysis data.

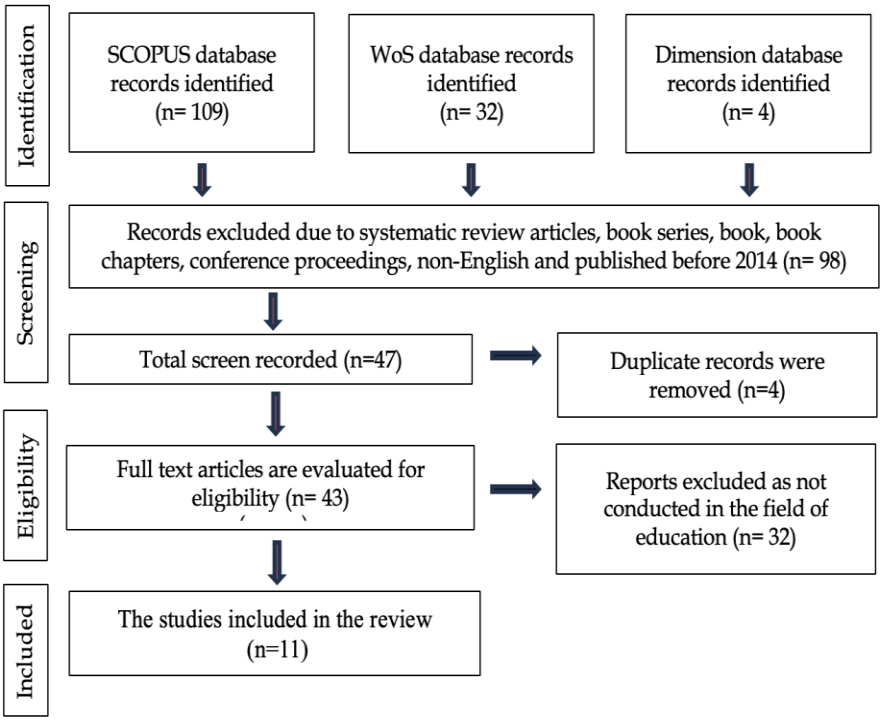

Figure 1: Study flow diagram (Page et al., 2021)

2.3.1 *Identification*

The identification process involves searching for synonyms, related terms, and variations of the main keywords used in a study. The goal is to provide additional database options for searching related articles to improve the review process. Based on the research questions formulated, three main keywords were identified: Six Sigma, DMAIC, and quality tools. In this review, an advanced search was used to provide comprehensive search queries using field codes, Boolean operators, and proximity operators to narrow the search. Thus, Boolean operators (AND, OR, NOT, or AND NOT), phrase searches, truncation and wildcards ("*"), and field code functions (either by combining these search techniques or using them separately) were used to assist the search efforts (Grewal et al., 2016; Yusop et al., 2022). The identical search term was entered into the WoS database using the Title Search function (TS). The third database, Dimensions, was selected as an additional database. The researchers used Dimensions to search for related articles using the exact keywords used in Scopus and WoS. Table 1 shows the keywords used in the article selection. The search, using the three databases of Scopus, WoS, and Dimensions, resulted in 145 articles.

Table 1: Search string used in the SLR process

Database	Keyword Used
Scopus	TITLE-ABS-KEY (*six AND sigma* OR *6s* OR *six AND sigma AND tools* OR *six AND sigma AND technique* OR *six AND sigma AND quality*)
Web of Science	TS = (*six AND sigma* OR *6s* OR *six AND sigma AND tools* OR *six AND sigma AND technique* OR *six AND sigma AND quality*)
Dimensions	Using specified keywords from Scopus and WoS, as well as Boolean operators, phrase searches, and field code functions (where appropriate)

2.3.2 *Screening*

Screening the articles generated from the database in the first phase is the second step. The screening process is based on several acceptance and rejection criteria. For SLR, five criteria were established: the year of publication, the type of reference material, the language, the methodology, and the subject area of the journal articles. The criterion for the year of publication includes articles published in the last ten years from 2014 to 2023; as Okoli (2015) suggested, researchers should determine the range of time they can review. The reason for limiting the search to 2023 was that the investigation started in May 2023, while the year is still ongoing. Next, duplicate articles that were found in different databases were removed. At the same time, only journal articles were selected, while SLR articles, books, proceedings, dissertations, and conferences were excluded from this study. In addition, only articles published in English were included in the study to avoid misunderstanding. The methodology chosen in each journal article was a quantitative, qualitative, and mixed methods approach. Finally, the use of Six Sigma quality tools in school and higher education institutions was selected as the research subject for this study.

The criteria for selecting or rejecting journal articles for this study are presented in Table 2. During this process, 98 articles were excluded because they did not meet the inclusion criteria, and four duplicate articles were removed. The remaining 43 articles were used for the third selection process.

Table 2: The exclusion and inclusion criteria

Criterion	Inclusion	Exclusion
Year of publication	Publications from 2014-2023	Publications before the year 2014
Type of reference material	Journal articles	Theses, proceedings, books, and conferences.
Language	English	Indonesian, Malay, and others.
Methodology	Quantitative, qualitative, mixed methods.	Systematic literature review
Field of study	Education	Others

2.3.3 Eligibility

In the third phase, the researcher verifies the suitability of the articles found by manually checking them to determine whether they meet the criteria of the screening process. In this phase, only those articles that met all the requirements in the first two steps and met the eligibility criteria were selected. A total of 43 articles were reviewed to determine whether they met the criteria for inclusion in the study and were consistent with the objectives of the current study. Each article was selected by a detailed reading of the title, abstract, results, and author-annotated discussion. After eliminating 32 articles, only 11 potential publications remained suitable for further analysis. The 32 articles that were rejected were not from the field of education.

2.3.4 Inclusions

The final step was to select the articles that met all of the criteria for analysis. In this study, 11 selected articles passed all of the selection procedures. According to Robinson and Lowe (2015), the recommended number of articles to be included in the SLR is 50 at most and usually fewer than 10. Therefore, the number of 11 articles is sufficient to perform the SLR and provide a holistic analysis of the results. Below, the list of selected journal articles is provided in Table 3, each with the author's name, year of publication, and study title.

Table 3: Summary of the selected articles

Author	Country	Title
(Abdulla & Kavilal, 2022)	India	Analytical Investigation of Higher Education Quality Improvement by Using Six Sigma Approach
(Fatmasari, 2021)	Indonesia	Integration of Balanced Scorecard and Six Sigma in Measuring Open University Academic Services Performance
(Arafeh et al., 2021)	Jordan	Six Sigma Application for Raising Student Academic Achievement

(Sandu & Sharma, 2020)	India	Implementation of DMAIC Methodology of Six Sigma in Vocational Education and Training for Quality
(Alkoot 2019)	Kuwait	Using 6 Sigma to Improve Outcomes of Higher Education Institutes
(Bumjaid & Malik, 2019)	Bahrain	The Effect of Implementing Six Sigma Approach in Improving the Quality of Higher Education Institutions in Bahrain
(Milosavljevic et al., 2018)	Serbia	Implementation of Quality Tools in Higher Education Process
(Biju & Nair, 2017)	India	Measuring Academic Quality: A Three-Dimensional Approach For Internal Audit Using DMAIC
(Arafeh, 2016)	Jordan	Leveraging Six Sigma Tools and Methodology to Improve Student English Language Performance at Elementary School
(Al Kuwaiti & Subbarayalu, 2015)	Saudi Arabia	Appraisal Of Students Experience Survey (SES) As A Measure to Manage the Quality of Higher Education in The Kingdom of Saudi Arabia: An Institutional Study Using Six Sigma Model
(Mazumder, 2014)	United States	Applying Six Sigma in Higher Education Quality Improvement

3. Results

3.1 Countries and years in which research has been conducted on improving educational quality using Six Sigma quality tools.

3.1a Article Publication by Country

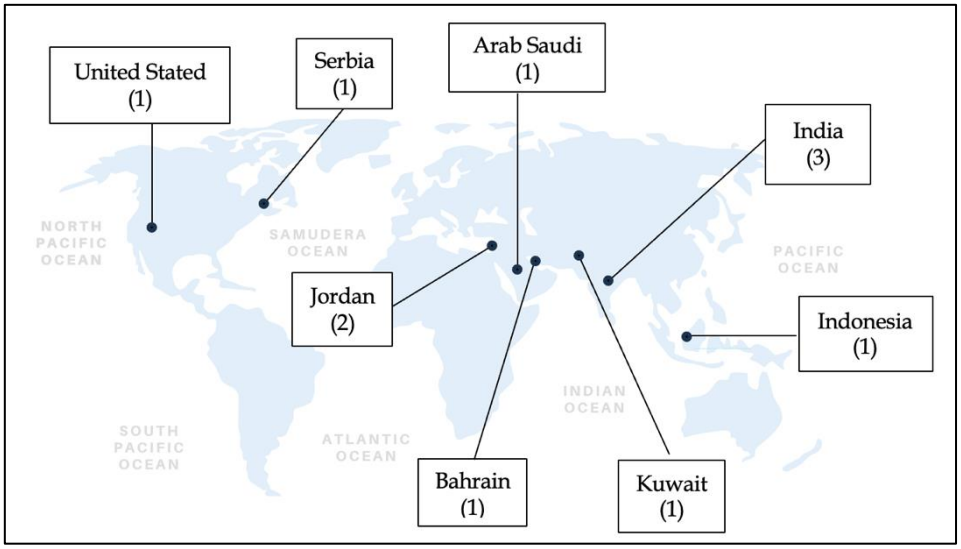

Figure 2: Distribution of articles based on countries

Figure 2 presents the distribution of article publication contributions by country. The chart reveals that eleven countries have published articles on using quality tools with the Six Sigma approach in education. The publications were produced in three continents, with 81.81% in Asia, 9.09% in Europe, and 9.09% in North America. Within the Asian continent, nine countries have contributed to the

publications. India had the highest contribution, with three articles by Abdulla and Kavilal (2022), Biju and Nair (2017), and Sandu and Sharma (2020). Two articles had been published in Jordan, by Arafeh (2016) and Arafeh et al. (2021), followed by Indonesia's Fatmasari (2021), Kuwait's Alkoot (2019), Bahrain's Bumjaid and Malik (2019) and Saudi Arabia's Al Kuwaiti and Subbarayalu (2015). The article published in the European continent originated from Serbia Milosavljevic et al. (2018), and that in the North American continent originated from the United States (Mazumder, 2014).

To date, only few articles exist on the use of Six Sigma quality tools in education. Moreover, no previous study has applied the Six Sigma concept in educational institutions in Malaysia to improve the quality of education regarding high-quality human capital success. The literature reviews conducted by Cudney et al. (2014, 2018) and LeMahieu et al. (2017) reveal that the Six Sigma approach, using various quality tools, has been used by most countries that want to ensure that their education system is one of the best in the world. This clearly shows a need to deepen and understand the use of Six Sigma quality tools in education, especially in Malaysia. If practiced effectively, national education can achieve its desired goal.

3.1b Publication of Articles Based on Year

Figure 3 illustrates the publication trend regarding the use of Six Sigma quality tools in education from 2014 to May 2023. To the present time, only 11 articles have been published in the last ten years, with only a limited number of publications each year. As of May 2023, there has yet been no publication of a study using Six Sigma quality tools in education. This highlights that the use of Six Sigma quality tools in education remains a new topic that has yet to gain acceptance in educational institutions. Nevertheless, several studies have demonstrated that Six Sigma quality tools can help systematically analyze and improve problems in education (Antony et al., 2021).

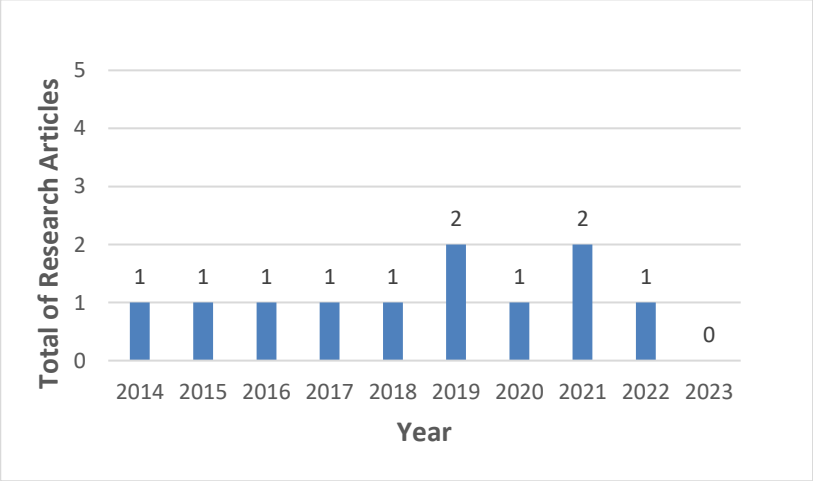

Figure 3 : Distribution of articles based on years

3.2 Improving educational quality as the focus of using Six Sigma quality tools in education

3.2a Categorizing Articles by Educational Level

According to Arafeh (2016) and Arafeh et al. (2021), there is a need for more evidence of using Six Sigma quality tools in schools. However, in higher education, 81.81% of institutions use Six Sigma tools to improve educational quality, according to studies (Abdulla et al., 2020; Al Kuwaiti & Subbarayalu, 2015; Biju & Nair, 2017; Bumjaid & Malik, 2019; Fatmasari, 2021; Alkoot, 2019; Mazumder, 2014; Milosavljevic et al., 2018; Sandu & Sharma, 2020). One reason is that a higher education role and responsibility in society is increasingly concerned with sustainability (Nadeau, 2017). Pursuing academic excellence is still necessary while "promoting and implementing sustainable practices in teaching, research, outreach, waste and energy management, and land use."

These nine articles have proven that Six Sigma quality tools can be used to resolve issues and problems in higher education institutions. Table 4 presents the results of the analysis, which revealed that the Six Sigma quality tool focuses on three areas of education: teaching and learning, administrative management, and academic performance. Therefore, the need to use Six Sigma quality tools to improve the quality of education at the school level is also high. School-level education is a critical level in any education system. After all, it is the foundation for students' academic development at a higher level (Olawoyin & Isuku, 2019).

3.2b Categorizing Articles by Educational Field

Based on the three areas of educational domains that were identified as using the Six Sigma quality tool, research into teaching and learning could be more extensive (Al Kuwaiti & Subbarayalu, 2015; Milosavljevic et al., 2018). Both of the existing studies focus on evaluating university instructors, and the results show that the tools have helped to improve the quality of the instructors. The systematic review results also reveal that using Six Sigma quality control tools helps improve teaching quality to achieve desired quality standards by identifying the cause of problems, analyzing the teaching process, taking appropriate action, and raising awareness of teaching quality. Nevertheless, there remains a need for further improvement because instructors are responsible for the quality of teaching and learning to enhance students' academic performance (Podungge et al., 2020). Therefore, improving the quality of instructors is crucial to address one of the problems in the education process (Ayieko et al., 2018; Gerritsen et al., 2016).

Several researchers (see Arafeh, 2016; Arafeh et al., 2021; Alkoot, 2019; and Mazumder, 2014) have evaluated the use of Six Sigma quality tools in education to improve student academic achievement. Analysis using the Six Sigma quality tool has helped school administrators and college leaders improve both the instructional process and student grades in subjects requiring attention. A total of five studies have investigated the use of Six Sigma quality tools in education to help college management evaluate academic programs in need of improvement and improve management quality (Abdulla & Kavilal, 2022; Biju & Nair, 2017; Bumjaid & Malik, 2019; Fatmasari, 2021; Sandu & Sharma, 2020). Table 4 presents the research focus of these studies, in terms of educational level and area of improvement.

Table 4: Stages of research samples and research focus

Authors	Level			Field in education		
	PRI	SEC	HEI	T&L	ADM	A&SP
Abdulla & Kavilal (2022)			√		√	
Fatmasari (2021)			√		√	
Arafeh et al. (2021)		√				√
Sandu & Sharma (2020)			√		√	
Alkoot (2019)			√			√
Bumjaid & Malik (2019)			√		√	
Milosavljevic et al. (2018)			√	√		
Biju & Nair (2017)			√		√	
Arafeh (2016)	√					√
Al Kuwaiti & Subbarayalu (2015)			√	√		
Mazumder (2014)			√			√

Legend
PRI = Primary
SEC = Secondary
HEI = Higher Education Institutions
T&L = Teaching and Learning
ADM = Administration
A&SP = Academic and Student Performance

3.3 Six Sigma quality tools that are generally used for quality improvement in education

The Six Sigma approach uses multiple quality tools to collect and analyze data and identify and improve problems or defects that occur in the process in order to meet customer needs (Fatmasari 2021; Jacobs & Chase 2016). Each Six Sigma quality tool is unique and has a different function. Therefore, selecting the appropriate Six Sigma quality tool for the problem at hand is critical. It is important to ensure that the process of evaluating and measuring the process analysis can be done accurately and effectively to ensure that quality improvements can be achieved. Table 5 shows the use of Six Sigma quality tools in education. As a result of the analysis, various Six Sigma quality tools have been used to improve quality and optimize processes in education. These Six Sigma quality tools are used in the Six Sigma phase of DMAIC and include suppliers, inputs, processes, outputs, and customers (SIPOC), Pareto analysis, fishbone technique, failure mode and effects analysis (FMEA), and statistical process control (SPC).

Table 5: Six Sigma Quality Tools in Education

Authors	Six Sigma Quality Tools				
	SIPOC	FB	PA	FMEA	SPC
Abdulla & Kavilal, (2022)	√	√	√		
Fatmasari, (2021)		√	√		
Arafeh et al., (2021)	√	√	√		
Sandu & Sharma, (2020)		√	√		
Alkoot, (2019)	√			√	√
(Bumjaid & Malik, 2019)	√	√			
Milosavljevic et al., (2018)		√	√		√

Biju & Nair, (2017)		√			
Arafeh, (2016)	√	√	√		
Al Kuwaiti & Subbarayalu, (2015)					
Mazumder, (2014)	√	√		√	

Legend
SIPOC = Suppliers, Inputs, Process, Outputs and Customers
FB = Fishbone Diagram
PA = Pareto Analysis
FMEA = Failure Mode and Effects
SPC = Statistical Process Control

A total of six articles have been published on the use of SIPOC (Abdulla & Kavilal, 2022; Arafeh, 2016; Arafeh et al., 2021; Bumjaid & Malik, 2019; Alkoot, 2019; Mazumder, 2014). SIPOC is an acronym for Suppliers, Inputs, Processes, Outputs, and Customers. It is a quality tool commonly used to identify each element in the improvement process before the actual process is implemented (Jacobs & Chase, 2016). Technically, SIPOC is a process mapping and improvement method that uses diagrams to summarize the inputs and outputs of one or more processes. SIPOC was used in the studies of Arafeh (2016) and Arafeh et al. (2021), which sought to improve the quality of teaching in schools by identifying the goals, methodology, and stakeholders whose needs must be met. At the same time, other studies (Abdulla & Kavilal, 2022; Bumjaid & Malik, 2019; Alkoot, 2019; Mazumder, 2014) use SIPOC as an analysis to identify the cause of the main problem and set a process goal that needs to be achieved. In the articles by Bumjaid and Malik (2019) and Alkoot (2019), SIPOC is used in the first phase of Six Sigma DMAIC before the project is developed to analyze the purpose and direction of the project to be carried out to improve quality. One of the benefits of the SIPOC quality tool in education is that it enables the user to identify who, what, and how to achieve the quality goals in education.

Fishbone diagrams are a popular quality tool in education. A total of 9 articles were identified in which fishbone diagrams are used to analyze information more deeply (Abdulla & Kavilal, 2022; Arafeh, 2016; Arafeh et al., 2021; Biju & Nair, 2017; Bumjaid & Malik, 2019; Fatmasari, 2021; Mazumder, 2014; Milosavljevic et al., 2018; Sandu & Sharma, 2020). A fishbone diagram is preferred and often used to list as many reasons as possible for an identified problem so that the root cause can be quickly identified and corrective action can be taken. Among the benefits of the fishbone diagram quality tool is that it successfully uncovered the root cause of student exam failure in the study by Milosavljevic et al. (2018), which was that the instructor's syllabus for most courses offered at the college was outdated. This quality tool also uncovered another cause, which was student absenteeism in class, causing students to fail to meet the requirements before the exam. To determine why the quality of vocational education in India is deteriorating, Sandu and Sharma (2020) also used this quality tool, and were able to successfully identify the causes affecting the quality of vocational education.

A total of six articles involve the Pareto diagram (Abdulla & Kavilal, 2022; Arafeh, 2016; Arafeh et al., 2021; Fatmasari, 2021; Milosavljevic et al., 2018; Sandu & Sharma, 2020). The Pareto chart combines two types of graphs: bar graphs and line graphs (Jacobs & Chase 2016). In the Pareto diagram, bar graphs are formed in descending order, from the most significant frequency to the least, while the graph is plotted according to frequency stacking from left to right. In other words, the Pareto diagram is a quality control tool used to determine the dominant factor with the most influence; in other words, it identifies the root of the problem that causes the most significant negative impact (Jacobs & Chase 2016). Among the advantages of the Pareto diagram is that it can compare data before and after the improvement, thereby confirming the effectiveness of the improvement actions.

The study by Arafeh et al. (2021) used the Pareto diagram quality tool in the third phase of the Six Sigma DMAIC to identify the causes of student underachievement. The evaluation results before the improvement process was implemented were listed, and the relevant indicators were identified as the causes. The analysis results were shared with customers (teachers, parents, students) to determine whether the indicators found were the leading cause of student failure. Then this quality tool was used to analyze the questionnaire results from customers. The development of the use of this quality tool before and after identifying the causes of students' underachievement is found by taking into account the principle of the Pareto diagram, which is that for many issues/problems, 80% of the effects come from 20% of the causes. Furthermore, a study by Sandu and Sharma (2020) used the Pareto diagram quality tool to detect why students undergoing practical experience performed poorly, and the result found that the leading cause was the dissatisfaction of practical students with the organization involved during the practical experience. The cause of this problem was detected and analyzed using the Pareto diagram.

Statistical process control (SPC) is a method used in quality control to monitor and improve the production process (Milosavljevic et al., 2018). This statistical tool is used to identify the causes of deviations, improve performance, and maintain high-quality levels of productivity control (Milosavljevic et al., 2018; Montgomery, 2019). Although SPC is typically associated with the manufacturing industry, this quality tool can be used in various settings, including education. Indeed, SPC has been used as a new method to evaluate faculty teaching effectiveness. As a result of the SPC quality tool, it was found that the causes of deficiencies included topics being too complex, faculty workload, and excessive class sizes. Furthermore, Alkoot (2019) and Milosavljevic et al. (2018) have used SPC to improve the quality of education in universities. Milosavljevic et al. (2018) demonstrated the strength of the SPC quality tool, which can identify and monitor subjects that do not meet college standards. Therefore, improvements in the educational process to reduce this deviation can be achieved by planning ways to minimize the number of subjects that still need to be passed. Alkoot (2019)'s study used SPC to determine the standard line of the process that needed to be achieved by identifying and determining whether the midterm or final exam could provide accurate information about the performance of students achieving the standard.

If a deviation is found during the process and the cause cannot be traced, SPC is used to find the root cause of the problem.

Failure Mode and Effects Analysis (FMEA) quality tools have the potential to analyze processes to identify failures and improve the quality of products or services offered. In other words, FMEA identifies defects that may occur, determines the cause of the defects, evaluates their effects, and determines the actions that must be taken to reduce or eliminate those defects. In the SLR study conducted, two articles were identified in which FMEA was used. In the study conducted by Alkoot (2019), FMEA was used in the second phase of Six Sigma DMAIC to plan and collect data related to student performance. All necessary information and data were collected and analyzed using FMEA. In the study by Mazumder (2014), FMEA is used in the fourth phase of Six Sigma DMAIC to determine the cause of low student performance. FMEA is used to improve this problem by analyzing the students, teaching staff, and curriculum.

4. Discussion

Few articles have been published on the use of Six Sigma quality tools in education during the last decade from 2014-2023, especially in Malaysia. An interesting finding is that Six Sigma quality tools have never been studied in the context of Malaysia's education system. However, the research also shows that India is a leader in publishing Six Sigma quality tools in education-related articles compared to other countries. Overall, the study has generated significant interest and opportunities for future research.

Past studies have also shown that the Six Sigma quality tool is widely used in higher education and positively impacts learning, teaching, management, and academics. According to the studies by Nadeau (2017) and Aziz (2021), Six Sigma quality tools are widely used in higher education as most universities compete to provide the best education to ensure that higher education standards remain high. However, the literature review suggests that its implementation in education could be more extensive, especially at the school level. To improve the educational process, educational evaluation at the school level should apply new measurement methods that use the Sigma concept and Six Sigma quality tools. Higher education is similar to school education in that both produce graduates, and factors such as curriculum, teaching and learning, infrastructure, and students' academic skills are necessary to ensure quality. Therefore, these factors are critical in any education system worldwide (Olawoyin & Isuku, 2019).

Six Sigma quality tools are used in various educational institutions, including teaching and learning, management, and the academic training of students. One successful application of this tool is to create a feedback system for students which can help in identifying the problems that are leading to their failure in course subjects. This tool has also improved the quality of college management by enhancing the technical input infrastructure, streamlining processes, and improving career fields and curricula. As a result, Six Sigma has significantly increased student academic achievement, making it a promising tool for transforming the education system toward higher standards. Therefore, the Six

Sigma quality tool is considered to be an effective new method that can enable improvements in the education system to achieve the expected standard.

This innovative approach has already proven successful in business and is now entering the field of education. Much of the literature shows that the most popular Six Sigma quality tools in educational institutions are SIPOC, Fishbone diagram, Pareto analysis, FMEA, and SPC to comprehensively analyze the Six Sigma DMAIC phases. With the help of this tool, an education system can become more successful and effective, leading to a higher level of excellence and bringing a national education system to a world-class level, of which the country can be proud. Therefore, implementing the Six Sigma quality tool in education is necessary to achieve the desired quality standard. The Six Sigma quality tools are a game changer for education, enabling the achievement of a high standard of education.

An important finding from this SLR study is that Six Sigma can be a comprehensive and effective strategy for continuous quality improvement in educational institutions by integrating various quality tools in the phases of Six Sigma DMAIC. In addition, the study results revealed that Six Sigma is a comprehensive and structured process that adds value and helps educational institutions to achieve desired quality standards and meet customer needs. The research findings determined that the Six Sigma quality tool is a process improvement tool that educational institutions can use to dig deeper into the root causes of problems in educational processes, enabling them to be resolved, reduced or mitigated, thereby allowing schools and educational institutes to achieve the desired quality standard (Mazumder, 2014; Taraza et al., 2023).

5. Conclusion

This SLR study found substantial evidence demonstrating that the use of Six Sigma quality tools in education plays an essential role in strengthening the quality of education for the successful attainment of high-quality human capital. The effectiveness of the Six Sigma quality tools approach is expected to reform the education sector, especially in the measurement field. Since the Six Sigma quality tools have a very high potential to be used to overcome problems, a continuous process is highly recommended to improve the quality of education. The use of Six Sigma quality tools will also lead to transformation in the education sector, bringing new methods such as brainstorming, critical analysis, and a new style of thinking that focuses on change to improve the quality of education. Therefore, educational institutions need innovative quality tools to diagnose problems and more accurately plan the most effective interventions. The best way to improve the quality of education is to use the Six Sigma quality tool to identify the strengths and weaknesses of the education process and take immediate improvement actions to enhance the quality of education. In other words, the Six Sigma approach, incorporating the Six Sigma quality tools, must be brought to the forefront of educational practise so that all actions and decisions can be made systematically, accompanied by accurate data and analysis methods; in this way, educational quality goals can be met. It has been demonstrated that improvement using the Sigma approach can significantly impact not only the members of the

school but also parents, the local community, and educational policymakers. One of the most critical factors contributing to the successful implementation of the Six Sigma quality tool is the strong desire of school administrators and policymakers for change, as their commitment will motivate the implementation of the change process.

6. Implications and Recommendations

The results of this study contribute vital insights in several main areas. First, this study adds value to the existing literature and understanding of the use of Six Sigma quality tools in education. It fills the research gap in terms of using assessment to diagnose problems in the educational process, from which to plan actions to improve the quality of education. Second, the findings encourage the expansion of the Six Sigma quality tools through more effective strategies to improve the quality of education in any field. Third, the precise theoretical contribution of Six Sigma quality tools, previously prevalent in the for-profit sector, can now be used in education. Fourth, it provides new insight that is valuable to the theory, field of measurement, and implementation of the Six Sigma quality tool, especially for the Ministry of Education in Malaysia. Fifth, stakeholders can use these findings to help diagnose the problems faced by the educational system in detail, allowing them to plan specific interventions to improve the quality of education. Therefore, further studies should be conducted on the effectiveness of Six Sigma quality tools for continuous performance in other areas of education. Through further research and application, studies on the effectiveness of Six Sigma quality tools, particularly in the Malaysian education context, will contribute significantly to the body of work.

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