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Lean manufacturing practices in an educational institution to improve the operational efficiency of a machine shop

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CHRONICLE

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ABSTRACT

The lean manufacturing approach is employed across several sectors to minimise waste and extend its ideas to institutional settings. The objective of this work is to provide instruction to aspiring engineers regarding the implementation and utilisation of lean tools. The machine shop of an engineering college utilised several tools, including 5S, standard work, and machine maintenance. The students were educated on the difficulties and achievements associated with the implementation of lean ideas across several tiers within the machine shop. The findings indicate that it is imperative to remove non-value-added operations, commonly referred to as Muda, in any manifestation inside the shop. A sequence of 5S audits was carried out to facilitate the enhancement of KAIZEN initiatives and uphold the shop's commitment to lean principles. The determination and assessment of the influence of lean tools on the Machine Shop were conducted through the utilisation of a questionnaire employing a five-point Likert scale. Following the implementation of lean principles, there has been a notable enhancement in several aspects. Specifically, there has been a 6.6% improvement in space utilisation, a substantial 95.12% increase in safety measures, a significant reduction of 83.3% in machine failure occurrences, and a noteworthy decrease of 80.2% in the time required for tool search.

1. Introduction

Lean Manufacturing is a systematic approach that is employed to decrease waste within the manufacturing process, with the ultimate goal of reducing various types of waste. However, the implementation of lean principles in enterprises and universities has been of minimal significance due to a lack of interest in adopting these concepts and preparing students for the sector. Professional continuous improvement solutions, such as the 5S methodology for workplace standardisation, may effectively bridge the gap that exists between educational laboratories and industrial services due to their shared characteristics. The ideas of the Lean manufacturing method have been widely disseminated throughout many organisations on a worldwide scale. Lean production, often known as the Toyota Production System (TPS), has its origins in the manufacturing industry. It provides comprehensive direction to many sectors within industrial organisations, aiming to achieve improved outcomes and enhancements across all areas (Osada, 1991; Kobayashi, 2009; Gapp et al., 2003). The implementation of lean tools and concepts in a machine shop facilitates the reduction of various types of waste and promotes a continuous flow of production. The user has provided a numerical reference without any accompanying text. The 5S methodology is a contemporary management style originating from Japan, designed to enhance the culture and environment of industrial organisations. The use of the 5S methodology was introduced to the company in 1980 by Takashi Osada and Hutchins (Kobayashi, 2009; Hutchins, 2007). The 5S principles encompass a set of five processes derived from the Japanese practice known as Seiri (sorting), Seiton (setting in order), Seisou (cleaning), Seiketsu (standardising), and Shitsuke (sustaining). These strategies are employed at a cheap cost

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to enhance efficiency and effectiveness in the workplace. The use of the 5S method enables the standardisation of the workplace and system, resulting in a safer environment within our laboratory. The successful application of 5S approaches inside an organisation has been shown to enhance employee performance and foster positive job attitudes (Sharma & Singh, 2015). The successful application of the '5S' methodology resulted in significant changes inside the organisation, encompassing improvements in working conditions, occupational safety, and employee happiness.

The present research case study was conducted within the context of an engineering college machine shop with the aim of enhancing and establishing a standardised work environment through the implementation of a continuous improvement method (Ebuetse, 2018; Oliveira et al., 2017). The researcher observed the machine shop of an established institution and identified the necessity of implementing the 5S methodology. Prior to and after the implementation, the study population was questioned in order to evaluate the purported influence of 5S, using certain performance criteria. The study was partitioned into three distinct portions. The primary objective was formulating a comprehensive approach for the successful execution of the 5S methodology within a machine shop setting. The subsequent procedure involved the implementation of the 5S methodology within the tool room of a machine shop. The last stage involved evaluating the efficacy of the 5S methodology and formulating suggestions based on the outcomes.

During the trial implementation, several obstacles were encountered in the process implementation (Attri et al., 2017). In order to address these obstacles, our research has shown that the implementation of the 5S methodology is an optimal approach for enhancing skill acquisition and knowledge growth among students and technicians. This methodology instills a sense of consciousness among the personnel and has been seen to yield noteworthy alterations in both attitude and conduct. The use of 5S gained significant traction within the manufacturing sector from its inception. Due to its simplicity and consistent methodology, the implementation of the 5S system has shown to be a beneficial practice for production and manufacturing companies, making it a widely adopted strategy across several industries (Veres et al., 2018; Ashraf et al., 2017). Nevertheless, the adoption of 5S in academic workshops and laboratories is still in its early phases. The objective of incorporating these strategies in workshops is to effectively address the disparity between the skill sets of students and the requirements of the business (Moss et al., 2013). Consequently, colleges are actively seeking methods to address the disparity, with the aim of offering impactful practical experiences within a hygienic and well-structured professional setting. Jiménez (year) discovered that the use of the 5S methodology has the potential to enhance cleanliness and minimise inventory and scrap inside educational workshops and labs (Jiménez et al., 2015). Consequently, the implementation of the 5S system enables the identification of Muda, or waste, and facilitates the discovery of strategies to eradicate it by minimising non-value-added activities related to mobility. This, in turn, leads to a reduction in the need for men to move in search of manufacturing equipment or tools. The adoption of 5S in workshop and mechanical laboratories has been examined by a researcher, who has highlighted the positive impact of 5S on several aspects such as the effective utilisation of machines and tools, efficiency of the machines, utilisation of lab workspace, safety, equipment search time, and the creation of a healthy atmosphere (Verghese et al., 2018; Dogan et al., 2014; Maharjan & Shyam, 2011; Sari et al., 2017).

The research study demonstrates the impact of implementing the 5S methodology in a workshop setting. This is achieved via the analysis of a series of images taken both before and after the implementation process. The findings indicate that the application of 5S resulted in a safer, more efficient, and cleaner laboratory environment (Dogan et al., 2014). The introduction of the 5S methodology in a medical laboratory within a university hospital resulted in the development of an enhanced culture surrounding the execution of studies. Sari et al. (year) elucidate the positive impact of using the 5S methodology on fostering a conducive work culture and ensuring a safe working environment. Jiménez (2013) elucidates the process of developing a 5S culture, emphasising the crucial role played by individual dedication and the ongoing pursuit of improvement. The research was conducted within the machine shop of a higher educational institution, including all stages, with the aim of enhancing the workplace environment and tool room.

2. Statement of the problems

The compilation of issues existed prior to the adoption of the 5S methodologies.

1. The work area does not exhibit effective utilisation for the storage of raw materials, tools, components, finished products, and scraps.
2. The inefficiency in locating necessary work pieces, tools, and components is attributed to the poor storage position, resulting in time wastage throughout the search process.
3. The morale of technicians and students is diminished as a result of the presence of extraneous materials being stored within the shop.
4. The cost of inventory is elevated as a result of the storage of superfluous items.
5. The absence of adherence to established standards in training procedures has resulted in an escalation of both work-related challenges and issues with tools and equipment.
6. Insufficient maintenance of machinery results in operational failure and mechanical breakdown.
7. Insufficient safety protocols were implemented, resulting in an unfavourable working environment.

Significance of research

The primary objective of this research was to employ the 5S approach in order to standardise and enhance the ergonomics of the machine shop. The intention was to provide a comprehensive framework that can be replicated by other organisations, universities, laboratories, or businesses with comparable requirements, hence enabling effective implementation. Additionally, it explored the benefits of using the 5S principles in a laboratory setting. This study emphasised the advantages of employing this method in order to enhance safety, reduce tool search time, optimise the laboratory working environment, streamline the workspace, and increase overall productivity inside a machine shop.

Hypothesis

The subsequent statement presents the research hypothesis:

1. The use of the 5S methodology is expected to result in an improvement in efficiency.
2. The implementation of 5S will result in an increase in the available space.
3. The integration of 5S is expected to result in a reduction in tool search time.
4. The use of the 5S methodology is expected to enhance the working environment of the Machine Shop.
5. The use of the 5S methodology will lead to an enhancement in safety measures.

Assumptions

The present investigation made some assumptions:

1. The participants showed a strong willingness to engage in the several stages of the study, which played a crucial role in facilitating the successful application of the 5S methodology.
2. The participants demonstrated honesty in their survey replies, as shown by the selected performance metrics.
3. The selected timeline for the implementation of the 5S methodology was deemed suitable.

Objective

The primary objective is to provide students with education and training in lean manufacturing processes, with the aim of preparing them for the demands of the industry.

1. In order to enhance the operational efficiency of the Machine shop, it is proposed to use the principles of lean manufacturing.
2. The use of 5S Standard work, Visual Management, Kaizen, and TPM is necessary to enhance and sustain the standards and safety inside the shop.

3. Barriers in implementing lean tools

3.1 Lack of Support from Upper Management

In order to effectively apply lean tools inside the machine shop, it is imperative that management offers comprehensive assistance across all organisational levels. A robust vision, aim, and value system are essential for effective management in order to cultivate a culture of excellence inside the company. It is important for management to provide support to young researchers' ideas in order to foster a secure and efficient working environment (Mudgal et al., 2010; Raj & Attri, 2011; Talib et al., 2011). It is important for students to engage in regular practice and actively cultivate their knowledge and abilities, as this will greatly benefit them upon their entry into the professional sphere (citation 20). Fig. 1 depicts the cause-and-effect diagram illustrating the many hurdles encountered during the implementation process.

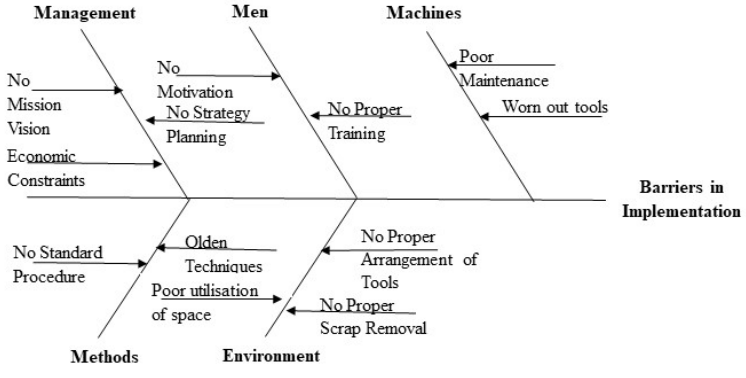

Fig. 1. Cause effect diagram of barriers in implementing the 5S.

3.2 The presence of economic limitations

One of the primary limitations is the allocation of cash by top management, who may choose to just partially cover the expenditures and offer assistance to enhance the implementation process (Lunt & Ball, 2012). The progress in technology facilitates students in acquiring a highly efficient learning approach that aligns with their educational level, so enhancing their prospects for a prosperous professional trajectory**.**

3.3 The absence of strategic planning

The aforementioned obstacle poses a significant challenge to the successful adoption and use of lean tools. The absence of adaptation to contemporary techniques and technology results in a perpetuation of traditional learning methods among pupils. The user provided a numerical reference (Lunt & Ball, 2012). The adoption of current manufacturing trends is necessary in order to equip students with the most contemporary skills and enhance their efficiency in the business.

3.4 Lack of commitment to coordinate and work in team

One of the primary challenges associated with applying lean principles is a notable lack of enthusiasm towards acquiring knowledge about new technologies and their corresponding implementations. The primary obstacle to implementation arises when the workforce exhibits resistance towards embracing and incorporating new practices. The initial personnel must undergo training in novel methodologies in order to effectively impart information to pupils, hence ensuring the quality of education (Raj & Attri, 2011).

3.5 Lack of Adequate Motivation

Another contributing element to the delay in adopting processes is the demotivation of employees by management. Motivation is widely recognised as a pivotal determinant in the achievement of effective execution. In order to effectively impart optimal techniques, it is imperative for management to be driven by the fulfilment of essential staff requirements. In order to address these issues, researchers opt to provide students with education on lean manufacturing principles and subsequently implement them within the machine shop.

4. Methodology

In this study, the researchers utilised the Seri, Seiton, Seiso, Seiketsu, Shitsuke, and Safety principles, together with visual management, to investigate the integration of lean principles inside an educational institution. The objective was to assess the impact of this implementation on students' learning efficiency and their ability to apply these principles within industrial settings (Raj & Attri, 2011). Fig. 2 illustrates the procedural approach employed for the deployment of the 5S technique within a machine shop setting.

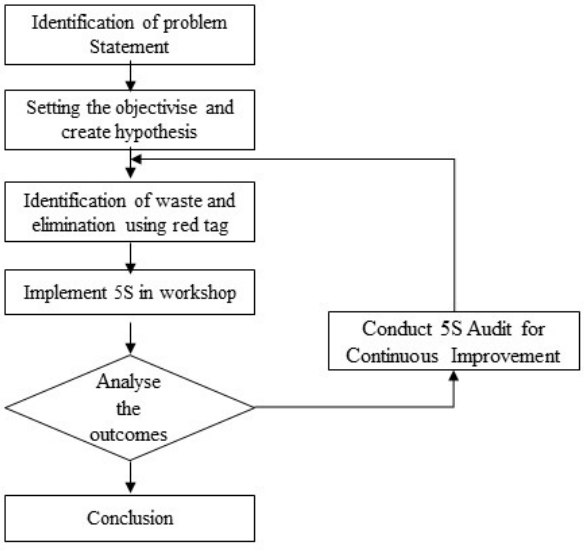

Fig. 2. Methodology to Implement 5S in machine shop

The use of a method that is extensively employed across many industries aims to enhance the efficient and effective utilisation of the environment. This method is employed to improve the standardised system of work for students, enabling them to acquire industry-specific knowledge from a foundational level and develop the necessary skills to be prepared for the industry.

The 5S+S technique is a fundamental approach that is extensively employed in production and manufacturing organisations to uphold the level of quality in the working environment while ensuring safety.

The 5S+S methodology consists of six key principles: Seri, Seiton, Seiso, Seiketsu, Shitsuke, and Safety. The planning strategy is a systematic technique that aims to achieve anticipated outcomes via the careful execution and implementation of plans. The user has provided a numerical reference without any accompanying text. The 5S is a set of five Japanese words that symbolise the five phases of a process.

Seri (Sorting) A Method for Systematically Removing Unnecessary Items in a Shop. According to the source Osada (1991), there are waste materials, old products, and aged tools that are deemed unfit for use in the store. The removal of unnecessary tools and materials results in the creation of unoccupied space. The Red Tag approach is employed as a means to eliminate the process of material sorting. According to the principles of the 5S methodology, Seiton, also known as "Set in order," is a crucial step in organising and optimising workplace efficiency.

In order to enhance efficiency, it is important to systematically organise the required materials, completed tasks, work pieces, tools, equipment, and parts, with the aim of eliminating any inefficiencies (Gapp et al., 2008; Kobayashi, 2009). The implementation of a set in order system establishes a uniform and consistent method for organising and accessing tools and materials. The user has provided a numerical reference.

The concept of “Seiso” refers to the practice of shining and cleaning, which is commonly observed in many contexts. Maintaining cleanliness of the work environment, including workplace areas, equipment, tools, and machinery, is essential for ensuring a tidy, safe, and conducive atmosphere for work (Massey & Williams, 2005). This phenomenon leads to a decrease in the occurrence of accidents and mechanical failures.

Standardisation and visual management, commonly referred to as “Seikestu”, is a methodology used in several industries to improve efficiency and effectiveness. This approach involves establishing standardised processes and implementing visual tools to enhance communication.

In order to uphold a standardised work procedure inside the business and ensure the preservation of work quality at all levels (Naqvi, 2013). The collection of schedules and checklists that are systematically adhered to in order to ensure consistent execution of each phase of the 5S methodology on a daily basis. The practice of constructing a visual workspace facilitates effective communication within a work environment, utilising non-verbal means of conveying information. The visibility of a workplace has been found to have a positive impact on several aspects, including reduced working hours, lowered equipment search time, and minimised inefficient procedures or systems (Chapman, 2005).

Shitsuke, also known as Sustain and Discipline, involves the ongoing education and training of both staff and students, with the aim of fostering a sense of personal dedication to the practices being taught. Sustainment contributes to the maintenance of motivation among both staff and students. Subsequently, it develops into a recurring pattern of behaviour and assumes the form of the prevailing organisational culture (Massey & Williams, 2005). Fig. 3 shows the 6S Methodology.

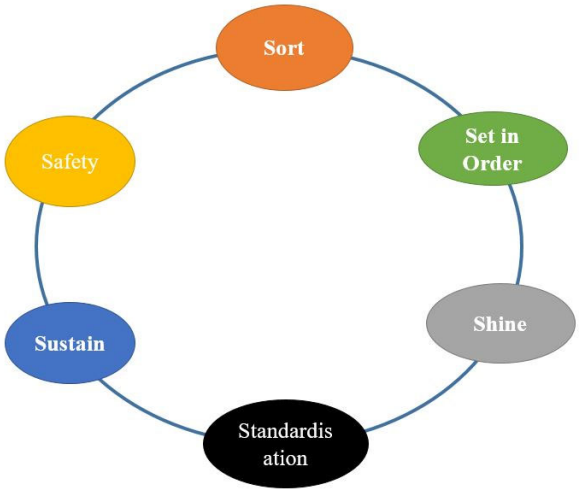

Fig. 2. 6S Methodology

Safety

In order to foster and maintain a heightened degree of safety within the production and manufacturing work environment. The objective is to establish and advance a secure work environment. In order to 231ptimize working conditions, it is necessary for both staff and students to adhere to the requirement of wearing appropriate gloves and shoes when inside the shop.

Red Tag

Sorting is a methodical process aimed at minimising superfluous and unneeded waste, known as Muda, within the machine shop. In the conducted case study, the red tag system was employed to effectively eliminate any and all types of undesired items within the tool room.

Visual Management

The technique in question is characterised by its lean nature. A visual workspace refers to a designated setting inside a work environment that is specifically designed to facilitate and enhance workplace improvements. The reduction of searching time enhances staff efficiency. The implementation of visual aids enhances and reinforces the overall work environment, labour methodology, and safety measures.

5S Audit

Following the introduction of the 5S+S methodology, it is necessary to undertake a 5S audit in order to facilitate ongoing improvement inside the machine shop and achieve excellence. A comprehensive set of audits was carried out in all sections of the machine shop to verify the continued effectiveness of the implemented sorting measures. The auditing process is conducted on a monthly basis by a team of professors from the mechanical department in order to verify and uphold the established standards.

The adoption of 5S has become ingrained as a cultural norm inside the institution and organisation, fostering an environment of ongoing enhancement and refinement. This process of ongoing improvement is commonly referred to as Kaizen. The term “Kaizen” originates from the Japanese language and denotes the concept of “improvement”. It is recommended that management, supervisors, and employees engage in regular review meetings, whether on a daily, weekly, or monthly basis, to discuss and evaluate the implementation of the 5S methodology.

5. The proposed approach for executing the plan

The selected methodology for execution entails the use of Deming's plan, do, check, and act (PDCA) cycle (Sidhu et al., 2013). Data was collected following the distribution of questionnaires over the duration of the planning phase. During the operating cycle, the Machine shop employs the 5S phases. During the third cycle assessment, evaluations are conducted using a 5S audit to determine the efficacy of 5S implementation and detect any possible areas for enhancement. The following phase, referred to as 5S, is subject to continuous monitoring within the Machine shop, where technicians are assessed based on their compliance with the specified 5S criteria (Kumar et al., 2022).

5.1 Survey for Feedback Analysis

In order to evaluate the student's assessment of the effects of implementing the 5S methodology in the Machine shop, feedback data was gathered using survey approaches. The survey consisted of a meticulously structured questionnaire, wherein identical questions were posed in a consistent sequence both before to and after to the deployment of the 5S methodology. Furthermore, the researchers monitored the search duration in addition to using instruments and a measuring gauge. The square footage of the work area was measured and documented prior to the deployment of the 5S methodology, and again after its implementation.

5.2 Data Analysis

The process of examining and interpreting data to uncover patterns, relationships, and insights is commonly referred to as data analysis. This study investigated the purported effectiveness, physical workspace, perceived duration of equipment searches, perceived working conditions, and perceived safety before and after the deployment of the 5S methodology. The survey administered before to implementation and after implementation consisted of a total of 20 questions. The alpha level for the significance test was established at 0.05, indicating a 95% confidence interval was utilised for the study. The effectiveness of the 5S implementation was assessed by the measurement of five specific items before and after its deployment. The study assessed the environmental conditions of the machine shop using a set of four questions (Questions: 1-4). Additionally, the arrangement of tools in the machine shop was evaluated using three questions (Questions: 5-8). The available space in the machine shop was measured through the implementation of three questions (Questions: 9-11). Furthermore, the safety protocols and practices in the machine shop were assessed using a series of five questions (Questions: 12-17). Lastly, the maintenance procedures in the machine shop were evaluated based on three questions (Questions: 18-20). The efficacy of the implementations is often measured using a five-level Likert scale. The point scales range from 1, representing a strong disagreement. I respectfully have a differing viewpoint. 3. I maintain a neutral stance on the matter and do not align myself with either agreement or disagreement. I concur. The user's response includes two statements: "Strongly agree" and "Not

applicable." The Likert scale technique is used to assess individuals' degree of agreement or disagreement with a given statement (Likert, 1932).

6. Results and Discussions

Following the introduction of lean principles, there was a statistically significant reduction ($p<0.05$) in the time required to complete tasks in the machine shop. Additionally, the overall look of the shop has been improved to provide a clean and safe environment, which has positively influenced the efficiency and performance of both students and staff ($p<0.05$).

The implementation of lean manufacturing tools was proposed as a means to eliminate all forms of waste from the machine shop. In order to ensure a safe work environment, it is important to maintain cleanliness in the work space throughout the day. The work pieces are categorised and organised individually according to their dimensions, form, and specific criteria**.** The utilisation of red tags serves the purpose of eliminating various types of waste inside the tool room, hence facilitating the creation of an efficient and productive work environment. The scrap material was systematically collected and stored in a designated area for efficient and expedited disposal. Table 1 presents the comparative data about the pre- and post-implementation outcomes of the 5S methodology inside the machine shop.

Fig. 3. Standardise the work piece

Fig. 4. Shine of Floor

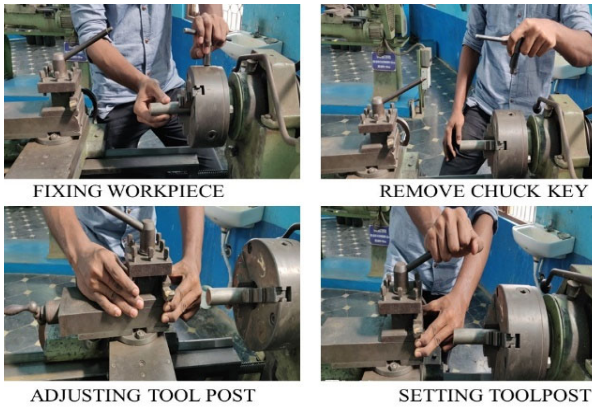

Fig. 5. Standard operating procedure to set the work piece

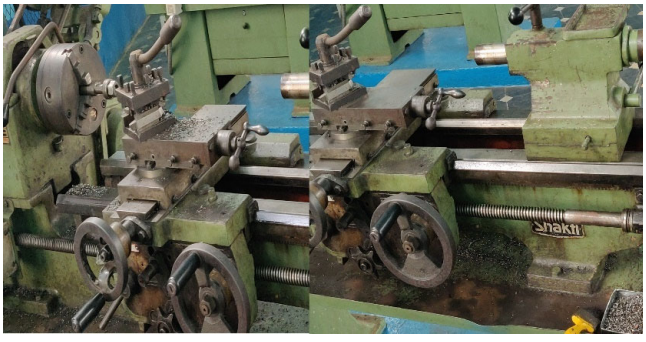

Fig. 6. Before and after cleaning and collecting the chips in Chip Tray

Table 1
Tool Search time in a month by continuous improvement

Trail	N	Pre-Impl (Sec)	Post Impl (Sec)	Save in time (Sec)
Week 1	5	156	138	18
Week 2	5	124	112	12
Week 3	5	115	98	17
Week 4*	5	190	103	87

Machine maintenance is performed at regular intervals according to a predetermined plan. The process of cleaning machinery is performed both before and following their usage. A chip tray was implemented in order to gather the chips and burrs that result from the machining process, which were then stored in the machine tray. The process of emptying chips from the machines is simplified, resulting in a reduction of time required for machine cleaning. Fig. 6 depicts the pre- and post-cleaning states of the machines, as well as the collection of scrap and chips in a tray. The indexing and labelling of each individual item within the tool has been implemented. The use of an indexing system facilitates the expeditious finding of tools and supplies. The Index sheet is positioned on the anterior surface of each cupboard. In order to minimise the duration required for doing a search. In a similar manner, we conduct regular inspections to ensure that the supplies and tools are appropriately stored in their designated locations. Table 1 illustrates the duration of search time within the establishment both prior to and

subsequent to the deployment of the 5S methodology. Periodic internal audits are conducted to guarantee the seamless functioning of the system within the machine shop. All deviations and corresponding remedial actions are documented to provide an effective workflow. The safety regulations were prominently shown at each machine with the purpose of reinforcing pupils' awareness of occupational safety. Fig. 7 depicts the audit report.

Fig. 7. 5S Audit report

Survey for Feedback Analysis

The objective of this pre-implementation and post-implementation study was to introduce the 5S methodology in a machine shop setting and examine its impact on many factors, including efficacy, spatial utilisation, search time for tools and measuring gauges, working conditions, and safety. Table 2 presents an examination of the arrangement space, safety, and maintenance of the instrument.

Table 2
Analysis on paired samples t-test results for Environment, Tool arrangement Space, Safety and Maintenance. α = 0.05

			Pre-Implement		Post Implement				
	N	df	Mean	SD	Mean	SD	Diff	t	P
Environment in Machine Shop	5	4	1.57	0.387	1.806	0.636	-0.236	-0.55	0.0062
Tool arrangement in Machine Shop	5	4	1.567	0.008	1.26	0.183	0.304	-3.71	0.0021
Space in Machine Shop (tool Room)	5	4	1.167	0.118	1.806	0.52	-0.639	-2.4	0.0096
Safety in Machine Shop	5	4	1.56	0.205	1.64	0.025	-0.139	-1.91	0.0097
Maintenance in Machine shop	5	4	1.528	0.196	1.833	0.491	-0.306	-1.16	0.0033

Hypothesis

Hypothesis 1: Following the implementation of the 5S methodology, there will be a noticeable improvement in the overall atmosphere of the machine shop. After implementation, the observed mean value ranged from 1.57 to 1.806. The statistical findings of this study were deemed to be both relevant and significant, as evidenced by the obtained t-value of -0.55 and a p-value less than .001. Therefore, the first null hypothesis was rejected. The machine shop undergoes regular cleaning and inspection procedures.

Hypothesis 2 (Tool arrangement in Machine Shop): The use of the 5S methodology resulted in a reduction in the time required to look for tools and gauges. The search time was operationally defined as the duration necessary to locate and retrieve tools and gauges. The statistical analysis reveals that there is a significant difference in the mean value following the implementation, as evidenced by a t-value of -3.71 and a p-value less than .05. Therefore, the null hypothesis 2 is rejected. The tool was categorised and systematically arranged to facilitate straightforward identification. In order to optimise efficiency in the process of looking for and retrieving tools, a comprehensive index of tools is prominently displayed within each area of closets.

Hypothesis 3 posits that the implementation of the 5S methodology results in an increase in the available space inside the machine shop, namely in the tool room. The tool room's overall space was 231.77 square feet. Following the completion of the implementation process, the aggregate size of the tool room was measured to be 247.12 square feet. There has been a 6.6% rise seen in the tool room. The enhancement of tool room safety is achieved by the mitigation of limited motion of the tool.

Hypothesis 4: The implementation of the 5S methodology resulted in an increase in safety inside the machine shop. The statistical analysis reveals that there is a significant difference in the mean value of the range 1.56 to 1.64 ($t = -1.91$, $p < .05$). Therefore, the null hypothesis 4 is rejected. The execution of experiments involving welding necessitates adherence to a suitable attire and the utilisation of safety gear, both of which are subject to inspection during the procedure. Consequently, the safety of the students is assured, thereby enhancing their incentive to engage in experimental activities.

Hypothesis 5 examines the concept of maintenance within a machine shop setting. The implementation of the 5S methodology has resulted in a reduction in machine maintenance and breakdown occurrences. The statistical analysis reveals that the mean value ranging from 1.528 to 1.833 exhibits significance ($t = -1.16$, $p < .05$). Therefore, the null hypothesis 5 is rejected. The students establish and adhere to a maintenance plan before and following their use of the devices. In addition, students get knowledge on the maintenance of machinery to ensure optimal functionality following each utilisation.

Fig. 8 shows the arrangements of tools before and after red tags.

Pre Implementation of 5S Post Implementation of 5S

Fig. 8. Red tags and sorting of tool room

The improvement in the organisation of the machine shop following the implementation of the 5S methodology was noted to have enhanced the safety of students, as it facilitated the simpler identification and accessibility of crucial equipment. The results of the study indicated that there was a significant increase in perceived efficiency. These findings provide support for the previous studies conducted by researchers (Kanamori et al., 2016; Ashraf et al., 2017), which showed that the implementation of 5S practices resulted in a reduction in equipment search time and an improvement in overall efficiency.

Despite the limitations imposed by building architecture and spatial constraints, there was a noticeable and tangible expansion in the machine shop tool room area. This expansion, however, may have impeded the efficient recovery of unnecessary workspace. Nevertheless, the data demonstrates that the use of the 5S methodology leads to an increase in available work space, enhanced safety measures, and the reclamation of shelf space through the elimination of unnecessary products. This observation aligns with previous research indicating that the use of the 5S methodology has led to an increase in floor utilisation. Additionally, it is consistent with other studies that have reported successful recovery of square footage through the application of similar strategies (Srinivasan et al., 2016; Ashraf et al., 2017).

The students saw notable enhancements in the machine shop environment following the implementation of the 5S methodology. The machine shop underwent thorough cleaning procedures at the beginning, conclusion, and periodically during each day. The correct disposal of leftovers and waste items is ensured (Zhang et al., 2021). This finding supports prior research that has demonstrated the effectiveness of using the 5S methodology in reducing the presence of undesirable products, promoting a clean environment, and enhancing safety (Kanamori et al., 2016; Srinivasan et al., 2016; Zhang et al., 2021; Singh & Ahuja, 2014).

The introduction of 5S was implemented within a four-week timeframe in the machine shop for the sake of this study; yet, it is generally acknowledged that the maintenance of 5S practices normally requires a longer duration. Consequently, the enduring advantages of 5S cannot be integrated into our research. Srinivasan et al. (2016) suggests that potential bias may have been introduced in the surveys conducted one month following the 5S event, as a result of the 5S training and the expected gains.

It is recommended that training sessions and audits be conducted at the commencement of each academic semester to familiarise new students with the principles of 5S. This proactive approach is crucial in order to maintain the desired outcomes

associated with the implementation of 5S practices. Sustained training will ensure the enduring integration of the 5S methodology into the laboratory's organisational culture. Regular audits should be performed to guarantee the ongoing maintenance of achieved achievements.

7. Conclusion

The use of lean methodology in the machine shop of an engineering college offers a framework for establishing organisational value and embracing the principles of continuous improvement. The use of 5S standards has been found to enhance the efficiency of space utilisation, equipment maintenance, and the creation of a safe working environment. Regular internal audits and surveys contribute to the establishment of a clean and safe work environment. Consistently providing training sessions to students and technicians on the principles of 5S and safety contributes to maintaining a well-organized work environment inside the machine shop. The findings of the study indicate that the implementation of 5S in the machine shop, with the aim of standardising and offering students a chance for industrial learning, is a justifiable course of action.

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