MEJORA DEL DESARROLLO DE PRÁCTICAS EN EL TALLER DE SOLDADURA DEL ISU SUCRE CON LA IMPLEMENTACIÓN DE LA METODOLOGÍA 5S

IMPROVEMENT OF PRACTICE DEVELOPMENT IN THE WELDING WORKSHOP AT ISU SUCRE WITH THE IMPLEMENTATION OF THE 5S METHODOLOGY

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Resumen

El desarrollo de esta investigación tuvo como objetivo mejorar el orden, limpieza y seguridad en el taller de soldadura para un adecuado proceso enseñanza-aprendizaje en prácticas académicas de los estudiantes, por lo que se implementó la metodología 5S. Se utilizó un método cualitativo, para la recopilación de información, mediante registros fotográficos del estado actual y mal uso del espacio del taller de soldadura. Este proceso se complementó con un diseño descriptivo, iniciando con la observación in situ para posteriormente analizar mediante el instrumento árbol causa-efecto. El planteamiento de la metodología 5S inició con la clasificación de las máquinas y equipos completamente funcionales y de los que están fuera de servicio. Luego se ordenó las máquinas con sus respectivos módulos y las que requerían un mantenimiento fueron colocadas en un área de espera para realizar esta actividad próximamente. También se limpió el área de los módulos, se amplió el número de éstos y se repotenció el sistema de extracción. Esto se realizó con el fin de evitar accidentes por el desorden y evitar

que los estudiantes tengan problemas de salud por los gases tóxicos acumulados en el taller de soldadura. Para analizar los resultados de la implementación de la metodología 5S, se realizó una encuesta cerrada de satisfacción, antes y después, para validar las actividades correctivas acerca del orden de cada equipo, la acumulación de gases en el interior del taller y la recolección de basura. En las condiciones anteriores, el 40 % de encuestados estaba conforme con la situación del área de trabajo. Sin embargo, después de la implementación de esta metodología, el resultado mejoró significativamente, al alcanzar el 100 % de satisfacción, en Docentes y estudiantes que realizan prácticas de laboratorio en este espacio. Por último, se realizó un monitoreo durante un período de 8 semanas, donde se observó una disminución del orden del 7 % a partir de la tercera semana y una disminución máxima del 14 % al finalizar este tiempo de monitoreo. Si bien, los resultados fueron evidentes y demostraron que la implementación de la metodología 5S logró una mejora del 60 % en el orden y la limpieza del taller de soldadura, se requiere profundizar en el aspecto de la disciplina, ya que se sigue con una tendencia hacia la desorganización.

Palabras clave: Metodología 5S, Ordenar, Limpiar, Soldadura.

Abstract

This investigation was developed to improve order, cleanliness, and safety in the welding workshop for an adequate teaching-learning process in the students' practices, hence, the 5S methodology was implemented. A qualitative method was applied to collect information through photographic records of the current situation and misuse of the welding workshop space. This process was complemented with a descriptive design, starting with in-situ observation to later analyze by using the cause-effect tree as an instrument. The 5S methodology began with the classification of the machines and equipment that are fully functional and those that are out of service. Then, the machines were ordered with their respective modules and those that required maintenance were placed in a waiting area to perform this activity shortly. The area was also cleaned, the number of modules was increased and the extraction system was upgraded. This was done to avoid accidents related to the disorder and to prevent students from having health problems due to the toxic gases accumulated in the welding workshop. To analyze the results of the implementation of the 5S methodology, a closed satisfaction survey was conducted, before and after, to validate the corrective activities regarding the order of each equipment, the accumulation of gases inside the workshop, and garbage collection. Under the previous conditions, 40 % of respondents were satisfied with the situation in the work area. However, after the implementation of this methodology, the result improved significantly, reaching 100 % of satisfaction, among teachers and students who perform laboratory practices in this space. Finally, monitoring was carried out for 8 weeks, where a decrease of 7 % was observed from the third week onwards and a maximum decrease of 14 % at the end of this monitoring period. Although the results were evident and showed that the implementation of the 5S methodology achieved a 60 % improvement in the order and cleanliness of the welding workshop, it is necessary to deepen the aspect of discipline, since there is still a tendency towards disorganization.

Keywords: 5S Methodology, Order, Cleaning, Welding.

1. INTRODUCTION

Global technological advancements are introducing new challenges and heightening competitiveness in the modern landscape, characterized by rapid transformation. Particularly, the manufacturing and industrial production sectors have experienced significant upheavals in recent years. Consequently, organizations must pivot their objectives towards effectively responding to, managing, and adapting to these transformative shifts. In this dynamic era of continual technological evolution, internal management becomes imperative for companies aiming to remain competitive and foster innovation in their products or services. Achieving progress in this context necessitates the implementation of best practices, particularly in the pursuit of elevated standards of quality. The 5S methodology emerges as a prominent management tool within Lean Manufacturing due to its ability to effectively demonstrate and educate operators on waste elimination and proper workplace organization (Vargas-Rodriguez, 2018). Originating in the Japanese industry, the 5S methodology was developed by Takashi Osada to foster better quality, productivity, and safety within organizations (Piñeiro et al., 2018). The 5S methodology, encompassing the Japanese principles of Seiri (Sort), Seiton (Set in order), Seiso (Shine), Seiketsu (Standardize), and Shitsuke (Sustain), serves as a collective effort to address organizational growth challenges. Moreover, it instills a sense of systematic utilization and organization, facilitating efficient outcomes in the workplace. By simplifying the work environment and enhancing workplace safety, the 5S methodology complements organizational efforts by instilling order and discipline (De Souza et al., 2021).

2.DEVELOPMENT

2.1. State of the Art

Randhawa and Ahuja (2017) conducted a comprehensive study on the implementation of the 5S methodology across all organizational levels to underscore its impact. This approach has significantly enhanced the progress of numerous organizations in terms of quality, productivity, efficient space utilization, employee safety, and adherence to ethical standards. Their research not only highlights the positive production outcomes resulting from successful 5S initiatives but also sheds light on the challenges encountered during the implementation process. Consequently, the adoption of this methodology serves as a valuable tool for researchers and professionals seeking to gain insights into the success and sustainability of its implementation. In a separate study, Medrano-López et al. (2019) applied the 5S methodology in a spare parts warehouse. They provided photographic evidence depicting the initial condition of the area for comparison with the post-implementation results. The primary objective was to achieve alignment between the physical stock and the inventory recorded in the management system. The spare parts were classified according to various categories such as pneumatic-electric, hydraulic, mechanical, and consumables. Following the initial assessment of the warehouse, an effectiveness rating of 48% was determined. However, after 4 months of implementing the 5S methodology, this effectiveness significantly improved to 93 %.

Hernández-Lamprea et al. (2019) conducted a thorough examination of the impact of the 5S methodology on productivity, quality, organizational climate, and industrial safety. They began by identifying areas with the highest disorder and then conducted a survey to evaluate performance metrics and risk scenarios. In the first “S” step, red tags were utilized to label and remove non-useful items. The second “S” entailed a classification process, categorizing tools, process jobs, templates, and machinery accessories. Cleaning sessions were scheduled for each employee as part of the third “S,” while the fourth “S” involved painting, delineating, and labeling machines, floors, and work areas.

Lastly, the fifth "S" focused on instilling good habits among workers. Productivity was assessed using equations for partial productivity, revealing improvements in human productivity, energy, capital, and productivity factor by 39.76, 30.93%, 30.39, and 28.57 %, respectively. Rates of reworked parts, wasted parts, and hardware rejections decreased significantly by 62.93, 82.94, and 71.42 %, respectively. Organizational climate saw enhancements of 48.6 %, communication by 26.6 %, motivation by 29.5 %, cooperation by 30.9 %, sense of belonging by 36.1%, labor relations by 19.8 %, and leadership by 24.35 %. The study underscores the critical importance of industrial safety, which exhibited an impressive improvement of 85.7 %.

Agrahar et al. (2018) introduced the 5S methodology in a small-scale weighing scale industry. They utilized the Red-Tag strategy, facilitating the identification of unwanted items by assessing three key questions: Is it useful? How frequently is it used? How much is needed? In the subsequent phase, all tools were meticulously labeled with names and numbers, incorporating color-coded systems for efficient file organization, and employing small containers for the arrangement of smaller items, alongside the establishment of tool boards. In the third stage, the team identified the designated area and tools, ensuring that any malfunctioning equipment was promptly repaired for immediate use. For the fourth phase, they devised procedures and simple daily checklists to uphold the principles of the previous 3S. Finally, in the fifth and final stage, they installed slogans, signage, and bulletins promoting the 5S principles. The application of the 5S methodology yielded significant benefits including cost reduction, enhanced work efficiency, decreased tool losses, minimized time spent on tool retrieval, reduced maintenance expenses, and improved safety measures, thereby mitigating worker injuries.

Escalante-Torres (2021) delved into the line-balancing model to boost productivity within a tempered glass processing company. They pinpointed areas for improvement, emphasizing waste detection and elimination through the application of the 5S methodology until reaching the specified threshold for achieving optimal production. A comprehensive cost structure table was devised for both pre-and post-model development to gauge return on investment, aiming to ascertain if the investment would indeed enhance productivity. Following the implementation of the 5S methodology alongside the line balancing model and subsequent hypothesis testing, results indicated a tangible increase in productivity alongside improved procedural performance, coupled with a reduction in production costs as evidenced by the finalized cost structure. Furthermore, Camero-Jiménez (2021) scrutinized the application of Lean Manufacturing, particularly the fusion of 5S and Kaizen, to bolster productivity within the water-based adhesives production domain of a manufacturing firm. Recent studies within such enterprises over the past four years revealed subpar productivity levels, falling below the anticipated benchmark of 5 kg/h. The studies presented underscore the necessity for Kaizen and 5S methodologies to tailor improvement strategies based on carefully selected manufacturing paradigms. This adaptation unfolds in stages, commencing with case diagnosis, followed by design, implementation, and eventual results evaluation. These stages were meticulously executed over seven months from January to July 2019. At the culmination of the lean production approach, productivity outcomes were scrutinized, yielding an average of 5.58 kg/h. Before the adoption of Lean Manufacturing, the average productivity performance stood at 4.37 kg/h.

2.2 Problem Statement

According to Zevallos-Álvarez et al. (2018), a decade ago, developed markets experienced a significant shift. Consumers had reached a level of satisfaction with the fundamental attributes of products and began prioritizing

their unique features. This change in demand dynamics has shifted the landscape from a seller's market, favoring preferred manufacturers, to a buyer's market focused on consumer preferences. This trend is also evident in the supply sector, where the emphasis on goods delivery has shifted towards providing tailored services (Rey-Sacristán, 2020). The concept of 5S emerged as a response to this evolution, necessitating corresponding company restructuring. Its development has been fostered in recent years through campaigns within various progressive companies. In Japan, the 5S concept has become deeply ingrained, making it challenging to find factories and offices that haven't adopted at least some of its principles. However, despite its widespread recognition, many companies are merely scratching the surface. Veres et al. (2018) point out that few companies have genuinely utilized 5S to establish the foundation for their long-term business survival.

The Instituto Superior Universitario Sucre (ISU Sucre) is a public higher education institution located in Quito, dedicated to training technologists in fields centered on technological advancement and development. Offering a range of study areas, the institute aims to deliver comprehensive academic education, including the Electromechanical Career. Notably, the Welding Workshop provides hands-on experience in real-world processes. While it partially adheres to safety regulations, there's a need for an organization and cleanliness system to optimize practice development. In every industry, ensuring appropriate working conditions is paramount, going beyond mere industrial safety. As Veres et al. (2018) suggest, an organizational methodology stands out as the most effective means of enhancing production.

The 5S methodology serves as the cornerstone for implementing any improvement initiative. It employs a visual cleaning approach encompassing five activities tailored to establish a workspace conducive to visual control and practical tasks. As per Sarkar (2020), this methodology drives performance improvement in productive activities by reducing time, thereby enhancing overall productivity and outcomes. Additionally, operating in cluttered and unclean environments increases the risk of accidents such as bumps, falls, and damage to machinery or materials, often resulting from improper material placement or the accumulation of surplus or waste materials. Given the limited physical space of the Welding Workshop, the circulation of students, machines, and materials poses a challenge. Consequently, establishing an organization and cleanliness system becomes imperative. However, immediate results may not be feasible, necessitating collaboration between teachers and students to instill discipline and consistency, fostering a pleasant, enjoyable, and efficient environment over time. These challenges impede the teaching and practical learning process in the Welding subject, underscoring the need for implementing a methodology capable of transforming the practical environment.

Organization and order are not abstract concepts that can be fully grasped through explanation alone. Simply displaying them on signs and banners lacks substantial impact; rather, organization and order are practices that require active engagement. The principles of the 5S methodology are ingrained in the culture of industries in Japan and even extend to personal life, albeit often unconsciously (Veres et al., 2018). A practical application involves arranging tools, fire extinguishers, waste, towels, notebooks, rulers, keys, and other items in designated and appropriate locations. A cluttered and untidy work environment not only reduces efficiency but also dampens morale, as highlighted by San Sebastián and Socconini (2020). Despite their proven benefits, few factories, workshops, or offices adhere to the 5S methodology as a standard practice, mirroring how individuals tend to care for their personal belongings. Incorporating the habit of maintaining order and organization in daily workt

routines can significantly enhance work efficiency and overall quality of life in the predominant environment. Thus, the adoption of the 5S strategy holds importance, not merely as a passing trend, but as a fundamental shift in management approach. These principles lay the groundwork for enhancing individuals' lives and creating a more enriching workplace experience.

This study tackles the challenge of ensuring equitable skill development for all students in the Welding Workshop at ISU Sucre. The primary issue identified is the necessity to enhance conditions within the workshop, particularly addressing slag removal and disorder, which can detrimentally affect the efficiency and safety of welding processes. To address these challenges, the implementation of the 5S methodology is proposed. This methodology emphasizes organizing and cleaning the workplace while standardizing processes to improve efficiency and minimize wasted time. Through the application of the 5S methodology, significant improvements in student performance are anticipated, achieved by optimizing time and available resources. Furthermore, apart from enhancing efficiency and work quality, the 5S methodology also aids in preventing occupational hazards by fostering safe and organized practices. This will be accomplished by instilling habits such as sorting, organizing, and regularly cleaning the work environment. It is expected that this initiative will not only enhance student performance but also contribute to fostering a safer and more efficient work environment overall.

2.3 Methodology

In this project, data was collected through both photographs and a pre-and post-survey, aiming to validate the corrective actions to be implemented in the area. Consequently, a qualitative research approach has been adopted to address questions regarding how, why, and what aspects of this process. Additionally, a descriptive research level was employed to provide significant insights into the studied population, elucidating common, frequent, or existing factors. The investigative process utilized the deductive method, as described by Abreu (2020), enabling the determination of the characteristics of the specific reality under study through deduction or by deriving properties or statements from previously formulated propositions or general scientific laws. This method is focused on deducing conclusions based on evidence.

According to Veres et al. (2018), the 5S methodology originates from Japan and is aimed at organizing the workspace in a clean, efficient, and safe manner to achieve a productive work environment. The 5S methodology serves as a foundational approach for any company striving to be recognized as a responsible producer. While the concept of 5S shouldn't be new to companies, unfortunately, it often is. This method is closely associated with Japan's leadership under Deming for over 40 years and is a fundamental aspect of continuous improvement. As stated by Jackson (2022), the 5S methodology is a straightforward yet powerful quality practice that aids in identifying and eliminating waste in the workplace. It also facilitates the establishment and maintenance of a productive and quality-driven environment within an organization. By compelling companies to address overlooked problems, the 5S methodology prompts thorough problem analysis. The 5S methodology comprises five phases described using Japanese terms that give it its name, as depicted in Figure 1.

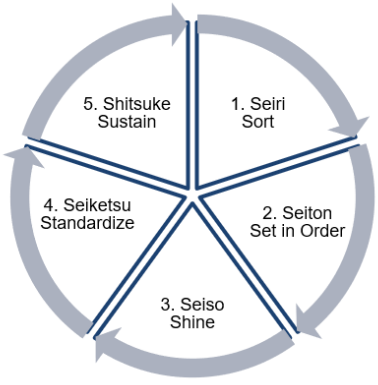

Figure 1. *Order of the 5S Methodology*
Source: Garrido (2018)

Figure 2 outlines the activities necessary to achieve tangible results for each phase of the methodology. As stated by Flores-Pérez (2020), effectively implementing each phase within companies is a mission-critical endeavor demanding robust tools. These tools and activities need not be complex or expensive; indeed, simple tools like bulletins and badges can be highly effective in fostering participation.

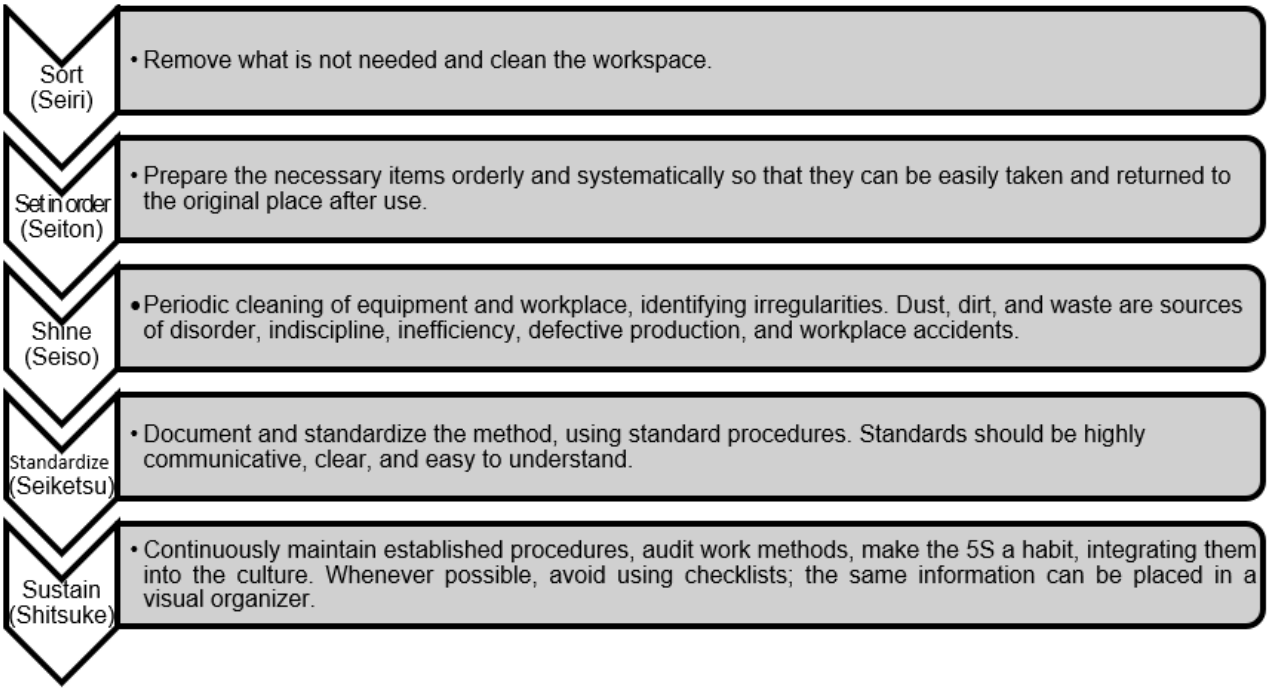

Figure 2. *Description of the 5S methodology*
Source: Garrido (2018)

After completing the mentioned activities, the classification tables were compiled. As a result of this process, 11 welders were identified, along with other machines and tools including a lathe, a pedestal drill, two grinders, a semi-automatic band saw, a hydraulic press, and two furnaces. The current functional condition of each of these machines and equipment is outlined in Table 1.

Table 1. *Identification of damaged and functioning equipment and tools.*

Equipment name	Quantity	Number of equipment in operation	Number of damaged equipment
Welders	11	5	6
Circular band saw	1	1	0
Pedestal grinder	2	2	0
Pedestal drill	1	1	0
Heat-treatment oven	2	2	0
Lathe machine	1	0	1
Hydraulic press	1	1	0
Total	**19**	**12**	**7**

The successful implementation of the 5S methodology hinges on understanding each term and its respective sequence for integration into the workspace. Initially, the first "S", Seiri, was utilized to categorize machines based on their consistent use in student practices within the welding workshop.

Subsequently, the second “S”, Seiton, was deployed to arrange the machines according to their modules, thereby expanding the laboratory practice area. The third “S”, Seiso, was then applied to eliminate accumulated gases, facilitating better visualization of practices and enhancing the overall environment of the welding laboratory through the implementation of an extraction system. Seiketsu, the fourth “S”, aims to standardize activities, ensuring compliance with the guidelines established in the initial three terms. The last “S”, Shitsuke, emphasizes discipline, highlighting the importance of adhering to the first four S’s, achievable through effective communication between teachers and students to foster a culture of organized work.

2.4 Results

Before commencing the implementation of the 5S methodology, several irregularities can be identified within the Welding Workshop, as illustrated in Figure 3. The research outcomes underscore a series of significant issues within the Welding Workshop at ISU Sucre. There is a noticeable lack of organization and cleanliness, evidenced by misplaced equipment and tools, obstructed passages, and inadequate handling of electrode holders. Furthermore, a deficiency in safety conditions is noted, with the accumulation of gases during welding practices and the common presence of electrode slag.

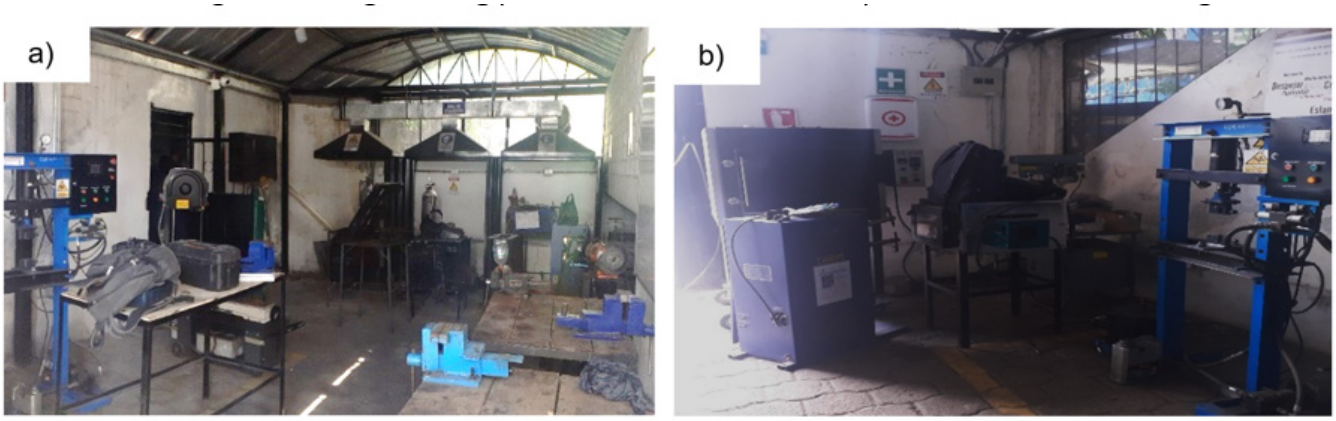

Figure 3. *Pre-existing conditions of the Welding Workshop: a) disorganization, b) unnecessary supplies.*

To more accurately assess these problems, a thorough inspection of the space was conducted through a closed survey, involving both responsible instructors and students utilizing the area. Survey findings indicated that 40 % of users were content with the order and cleanliness conditions, while the remaining 60 % identified disorder in the workshop, expressing discomfort from various perspectives. These results underscore a clear necessity to enhance conditions within the Welding Workshop, encompassing both organizational and cleanliness aspects, alongside the implementation of suitable safety measures. The survey outcomes lay a solid groundwork for the implementation of the 5S methodology, aimed at remedying these issues and significantly enhancing the working environment for all workshop users.

Table 2 lists the activities carried out for the validation of each term of the 5S methodology. The results obtained show significant progress in improving the Welding Workshop at ISU Sucre. One of the main highlighted improvements is the reorganization of the space, which has allowed for the separation of out-of-service equipment and the optimization of the available area for conducting practices. This action has not only facilitated access to the operational equipment but has also contributed to a more efficient distribution of space, thus enhancing the users’ experience. Additionally, a critical issue affecting all users, the accumulation of toxic gases during the welding process, has been effectively addressed. This concern has been practically resolved by upgrading the gas extraction system and installing hoods in the new modules.

These measures not only ensure a safer environment for conducting welding practices but also promote healthier working conditions for everyone involved in the workshop. These improvements are the direct result of attention paid to identified problems and demonstrate a continued commitment to excellence and continuous improvement in the educational and work environment.

Table 2. *Activities are carried out to validate each term.*

Term	Activity	Evidence
Seiri Sort	- Equipment Identification - Classification of operating machines and damaging equipment - List of required maintenance activities	
Seiton Set in order	- Waste disposal - Installation of additional modules - Location of machines in established modules	
Seiso Shine	- Repowering of the extraction system to avoid the accumulation of toxic gases - Installation of extraction hoods in the new modules - Cleaning and waste collection	
Seiketsu Standardize	- Dialogue with the Teachers in charge to convert regulations into habits - Placement of equipment identification, prevention, and information signage - Monitoring of the work area for information collection	
Shitsuke Sustain	- Socialization of the importance of industrial safety and work efficiency when maintaining an organized area - Promotion of generating a culture of order	

The outcomes of implementing the 5S methodology are vividly illustrated in Figure 4. It's imperative to underscore that cultivating habits of cleanliness and organization should be ingrained as recurrent practices, motivated by users' intrinsic drive. To this end, disseminating information that underscores the significance of industrial safety and the tangible productivity benefits resulting from consistently applying these straightforward actions has been prioritized. The concrete impact of the 5S approach is evident in the Welding Workshop, where a visibly more structured, hygienic, and secure atmosphere prevails.

These transformations not only amplify the efficiency and caliber of the work conducted but also instill a culture of accountability and dedication among workshop participants. It's paramount to stress that sustaining these cleanliness and organization standards demands ongoing commitment from all stakeholders involved. Hence, nurturing a proactive mindset that encourages regular engagement in these activities is indispensable for ensuring the longevity of the achieved enhancements and continual progress toward an optimal and secure working environment.

Figure 4. *The outcome of the implementation of the 5S methodology.*

2.5 Discussion

Despite the 5S methodology originating several decades ago, it remains rooted in the Japanese philosophy of continuous improvement, thus undergoing constant evolution. Lomparte-Cárdenas et al. (2022) synthesizes various implementations of this methodology in the industrial sector throughout 2021. It's worth highlighting that productivity and efficiency are enhanced through cleaning, organization, and standardization activities. Consequently, these activities, both conducted and proposed, served as a reference point to underpin the development of improvement initiatives and the evaluation of results in this study.

Standardization entails establishing precise procedures and norms to uphold the implemented working conditions and organization. In the context of the Welding Workshop, a checklist was employed, comprising the same survey administered both before and after project implementation over an eight-week duration, aimed at collecting information through monitoring. Figure 5 provides a visual representation of the percentage of order and disorder for each week, indicating that these parameters were at 40% before project implementation. In contrast, following the implementation of the 5S methodology activities, satisfaction reached 100%. Throughout the inspection period, there was a marginal decrease in order of 7% from the third week onwards and a peak decrease of 14% after the monitoring period, with a tendency to persist in disorganized behaviors.

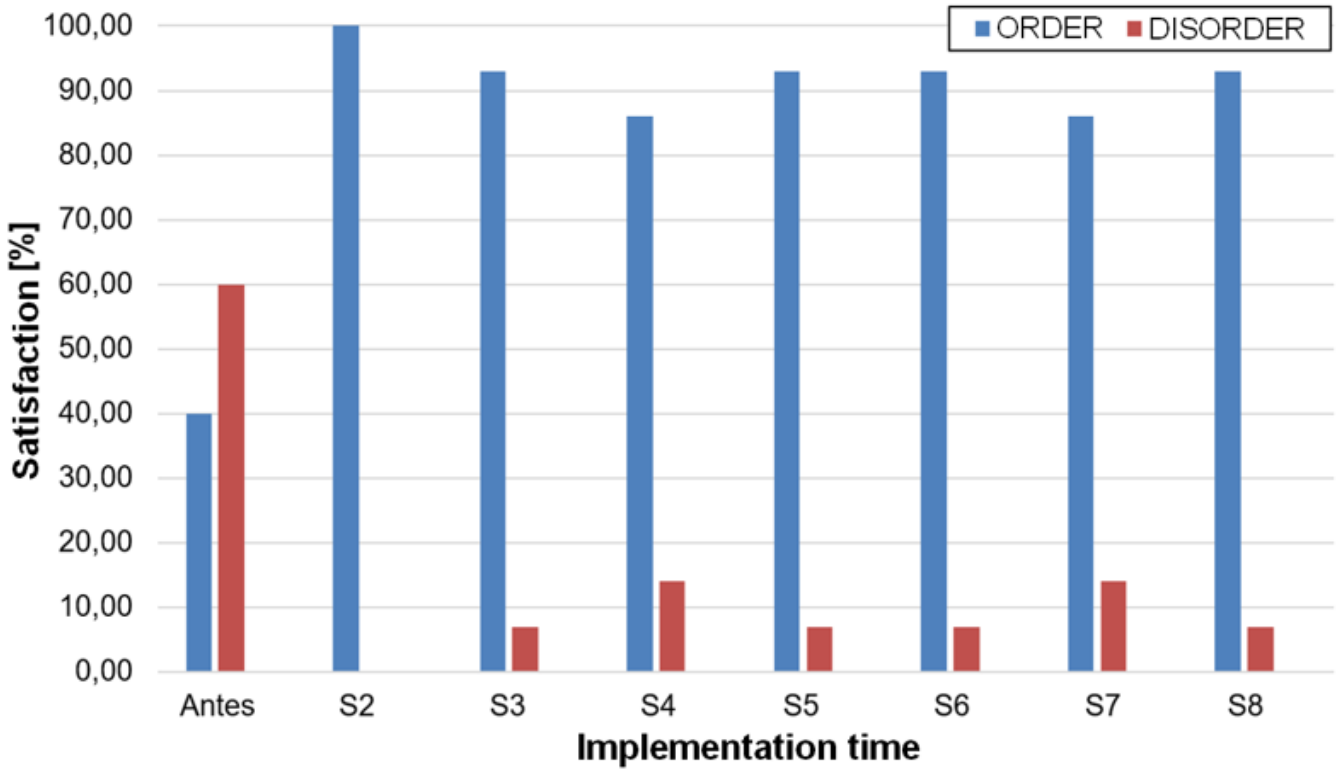

Figure 5. *Order and disorder percentage diagram.*
Note: *S is for weeks.*

Rizkya et al. (2019) implemented the 5S methodology in a welding workshop to reduce waste generation. The primary concern addressed in this research is the challenge of conducting activities in a confined space, which hampers working conditions. Consequently, the presence of debris exacerbates the issue, highlighting the need for proper organization and cleanliness. They achieved an 11.2% optimization of space, coupled with a reduction in waste presence of up to 19% over a six-month monitoring period. However, a trend becomes apparent in the results of this study: despite establishing regulations for organization and cleanliness, disorder gradually resurfaces, sometimes exceeding 10 % within a few weeks post-implementation.

3. Conclusions

Through this investigation, it was revealed that before the implementation of the 5S methodology, the Welding Workshop area within the Electromechanical Career was inadequate for student practices. A visual analysis pinpointed disorganization and cleanliness as the primary concerns. Information about the workshop's condition was collected and supported by photographic evidence, marking the beginning of the 5S methodology implementation, starting with organization. Ten welding machines were found, with five operational and six non-functional, alongside one band saw and two functioning grinders. Additionally, two operational heat treatment ovens were used in practices, while a pedestal drill was in good condition. Based on this, it was determined that 62.6 % of machines were in proper operational condition, with the remaining 37.4 % out of service. Consequently, the first two terms, Seiri and Seiton, were applied to categorize and organize the welders in their respective modules. The implementation of an exhaust gas extraction system ensured compliance with the third term, Seiso, enhancing productivity and providing a safe gas-free environment for students during practices.

To communicate the new working conditions, the fourth term, Seiketsu, focused on inspecting order and cleanliness, and a survey validated user satisfaction with the space. Initially, 60 % of users were dissatisfied with the conditions in the Welding Workshop; however, this significantly improved, reaching 100 % satisfaction after the implementation of the 5S methodology and improvement activities. Finally, the term Shitsuke emphasized discipline, aiming to educate laboratory users, students, and teachers on the proper equipment use.

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