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Implementation of 5S at a Survey Laboratory in Western Kentucky University

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IMPLEMENTATION OF 5S AT A SURVEY LABORATORY IN WESTERN KENTUCKY UNIVERSITY

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IMPLEMENTATION OF 5S AT A SURVEY LABORATORY IN WESTERN KENTUCKY UNIVERSITY

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To my parents, Dr. Christopher Ebuetse and Mrs. Stella Ebuetse, and siblings: Valentine Ebuetse, Mercy IB. Ebuetse, Victor Ebuetse, and Omoyemwem Imaseun who have believed in my capabilities and are quick to celebrate my small wins. I also dedicate this thesis to my fiancé, Etse Akpaibor for his moral support.

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IMPLEMENTATION OF 5S AT A SURVEY LABORATORY IN WESTERN KENTUCKY UNIVERSITY

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5S is a technique used alongside methodologies such as lean, total quality management and six-sigma for continuous improvement and workplace standardization. Nonetheless, despite the upsurge in the implementation of 5S by lean manufacturing facilities and other industries, educational laboratories appear to be lagging. Taking into consideration the benefits of implementing 5S within industry, it has become crucial to replicate the technique in an educational laboratory to obtain equivalent results. To upgrade educational laboratories into industrial laboratories, 5S (sort, set in order, shine, standardize, and sustain) is required to improve the laboratory's ergonomics that subsequently increases efficiency, productivity, and lessens waste amongst many other benefits. The aim of this study was to: first, standardize the surveying laboratory in Western Kentucky University by implementing 5S. Second, evaluate the impact of 5S based on the chosen performance indicators such as efficiency, workspace, equipment search time, working environment, and safety. To evaluate the impact of 5S on the selected performance indicators, study participants responded to a survey instrument pre and post 5S implementation. In addition, observations were made to assess the impact. The results showed that there was a perceived improvement in efficiency, workspace, equipment search time, working environment and safety.

Introduction

Background

5S is one of the first techniques used by organizations that adopt methodologies such as lean, total quality management, and six-sigma. Organizations learn that it is difficult to have well-defined operational procedures, improved working conditions, and quality products without 5S (Jugraj & Inderpreet, 2017). The 5S technique consists of five steps. In Japanese the words are *Seiri* (sort), *Seiton* (set-in-order), *Seisou* (shine), *Seiketsu* (standardize), and *Shitsuke* (sustain). 5S is a low-cost technique used by organizations to clean, order, organize, and standardize the workplace. This study implemented 5S in an educational laboratory. Using 5S, the laboratory was expected to improve in the areas of working environment, safety, reduction of equipment search time, and increased efficiency.

Educational laboratories that provide students with experiential learning that create knowledge through insights gained by practical experience has become an integral part of undergraduate STEM education (Reck, 2016). Universities and technical colleges aim to close the gap between theory and industrial practice using educational laboratories. These laboratories have technical resources and comparable functional characteristics with industrial facilities (Jimenez et. al., 2015). They prepare students with the skills required to work in a professional environment (Gibbins & Perkin, 2013). With shared similarities, the gap between educational laboratories and industrial facilities can be narrowed through the adoption of professional continuous improvement techniques such as the 5S for workplace standardization.

This study was conducted in the surveying laboratory in the Engineering and Biological Sciences building at Western Kentucky University (WKU), which is equipped to provide students with hands-on experiential knowledge during field data collection. The surveying laboratory seeks to provide students with the required experience. The laboratory practicums are conducted with this goal in mind.

The researcher visually observed the surveying laboratory in WKU and established the need to implement 5S. The study population were surveyed pre and post implementation to assess the perceived impact of 5S based on selected performance metrics. The study was divided into three parts. The first was to provide an approach for implementing 5S in an educational laboratory. The second was to implement 5S in a surveying laboratory. The third was to assess the benefit of 5S and present the results with future recommendations.

Problem Statement

From visual observation and conversation with faculty, the surveying laboratory requires organization as it has become unsafe for its users due to the clutter of equipment, unwanted boxes, long equipment search time, and congested workspace. Although the laboratory has some instructions, it is lacking in organization with little existing standardization in place or well-defined work procedures. It is critical that educational laboratories become standardized to improve lab ergonomics and prepare students for industrial careers. An unstandardized laboratory results in higher equipment search time, smaller workspace due to unwanted materials and equipment, reduced efficiency (i.e. longer time to carry out experiments), and poor working environment.

Significance of the Research

The significance of the research was to implement the 5S technique in standardizing and improving the ergonomics of the surveying laboratory by providing a framework for other professionals to successfully pursue its replication in similar educational laboratories or other industries. In addition, it also assessed the benefits of implementing the steps of 5S in an educational laboratory. The benefits of implementing the 5S technique in manufacturing and other industries have been extensively discussed in other studies. This study emphasized the benefits of applying this technique to improve safety and equipment search time, laboratory working environment, increase workspace, and efficiency in a surveying laboratory.

Purpose of the Research

The purpose of the research was to standardize and improve the ergonomics of the surveying laboratory in WKU by implementing the 5S technique. The expected results at the end of the research was shorter time for experiments, safer and cleaner environment for students, clearly labelled equipment areas to reduce equipment search time, and increased workspace for easier movement after unused items have been disposed. The purpose of the study was to assess the significant changes in performance metrics pre and post implementation of 5S in the laboratory.

Hypothesis

The study hypothesis follows:

1. After implementing 5S, efficiency will increase.
2. After implementing 5S, workspace will increase.

3. After implementing 5S, equipment search time will be reduced.

4. After implementing 5S, laboratory working environment will be improved.

5. After implementing 5S, safety will be improved.

Assumptions

The study assumed the following:

1. Participants were willing to take part in the distinct phases of the research that ensure the success of 5S implementation.

2. The participants were honest in their answers to the survey based on the selected performance measures.

3. The time-frame selected for the implementation of 5S was sufficient.

Limitations and Delimitations

The implementation of 5S requires participants having a basic understanding of the concept of 5S phases. The study is limited by the lack of previous knowledge about 5S by the participants, which might have affected the responses. In this study, 5S implementation was delimited to the surveying laboratory in Western Kentucky University. In addition, although 5S is a continuous improvement technique, its implementation was delimited to six weeks and one laboratory.

Definitions of Terms

Terms used during the study:

1. *Continuous Improvement (CI) Methodology*: These are methods that continuously improve processes and standards.

2. *Lean*: A methodology for eliminating seven types of wastes (muda) in a process.
3. *Standardization*: Standardization is the documentation of best practices in each process/project. If best practices are well documented there is room for continuous improvements.
4. *JIT*: According to Gunasekaran and Lyu, Just-in-Time is the method of producing what is needed, at the time needed, and in the amount needed (as cited in Singh & Ahuja, 2012, p. 67).
5. *Kaizen (Continuous Improvement)*: Kaizen is a Japanese word which means “incremental improvements” – quick and easy.
6. *PDCA (Plan, Do, Check, Act)*: The PDCA is a continuous improvement cycle, also referred to as Deming cycle or Shewhart cycle. According to Sokovic et al. (2010), PDCA cycle is an effective method of continuously seeking improvements and adopting “the right first time” approach.
7. *TQM (Total Quality Management)*: Total Quality Management is a continuous improvement strategy by management to instill a culture in the organization for delivering high-end quality products.
8. *TPM (Total Productive Maintenance)*: Total Productive Maintenance is a proactive strategy of scheduled maintenance of manufacturing equipment to prevent machine break-down or faults that will impact the quality of the product.
9. *TPS (Toyota Production System):* Toyota Production System is a production system developed by Toyota for the elimination of wasteful practices such as muda (waste), muri (overburden), and mura (unevenness) in production processes.

10. *Quality Cycle*: A sequence of activities aimed at improving processes or products. PDCA is often used.
11. *ISO*: International Organization for Standardization that establishes universal standards for production of products.
12. *IMS (Integrated Management System)*: Integrated Management System is the combination of individual management systems to develop an effective integrated manufacturing system.

Review of Literature

The review of literature serves the following purposes. First, provide an overview of 5S based on scholarly articles to provide a context for 5S implementation within organizations. It introduces the implementation strategy adopted in published works to create a framework for the implementation of 5S within an educational laboratory. Second, it identifies the existing gap in 5S implementation in other literature. According to Singh and Ahuja (2014), “despite the simplicity of 5S, organizations have had difficulties in its implementation” (p. 274). These difficulties are closely linked to existing gaps between theory and practice of 5S that is evident in many research papers (Kobayashi, 2009). The review of literature identifies the gaps by highlighting the misconceptions regarding 5S implementations. This critical examination aided in the strategy deployed for the implementation of 5S in this research. Third, the literature review highlights the benefits of 5S from studies undertaken by other researchers, which provides a benchmark for the study’s performance measurement.

The chapter is organized as follows. The first section gives a brief history and discusses diverse concepts of 5S. The second section discusses the components of 5S. The third section discusses implementation strategies and that were adopted for the study. The fourth section discusses the relationship between 5S and continuous improvement methodologies. The fifth section emphasis the applicability of 5S deployment in laboratories case studies. This section considers an educational laboratory to be a service related organization. As such, only service related case studies were discussed. The sixth section discusses the evaluation methods used to assess the benefit of 5S implementation and the seventh section lists some of the benefits of 5S implementation. The eighth and ninth sections discuss implementation barriers and misconceptions in the adoption of 5S in organizations. The review of published literature led to a broader approach for the research described in this thesis. The approach was outlined and justified.

History and Concept of 5S

In the early 1980s, the concept of 5S was developed by Takashi Osada in Japan. There is still considerable ambiguity about who developed the 5S concept in several literary articles. However, in a study by Patel and Thakkar (2014), Hiroyuki Hirano is credited as being the first to have developed 5S. According to Hirano (1995), 5S is defined as the first pillar of a visual workplace for organizations. Hirano further described 5S as a management approach for elimination of waste and process improvement. Congruently, Deshpande et al. (2015), defined 5S as a discipline for maintaining a visual workplace and for workplace management to reduce loss of time and unnecessary movements.

A general definition and practice for 5S is lacking. Ab Rahman et al. (2010), defined 5S as a technique used in the production line to improve environmental performance, housekeeping, health, and safety in production line. Likewise, Kaushik, Khatak, and Kaloniya (2011), defined 5S as a methodology that creates standardization in the workplace, improves working condition and quality, reduces waste, ensures safety of workers, maintains a clean workplace, and ensures that everyone adapts to 5S as a culture in the organization. In contrast, Ramesh et al. (2014), defined 5S as a "lean method and a system of process improvement that is adopted to reduce waste, clean workplace, and improve labour productivity" (p. 312).

In retrospect, 5S is often referred to as the foundation of lean and is the first step towards implementing lean manufacturing techniques. Delisle and Freiberg (2014) established that 5S may be underutilized in the context of lean and would be better off as a quality management or improvement framework. The use of 5S within total quality management systems makes it a substantial part of quality initiatives; a good housekeeping tool, an effective cleaning program, standardization, and a system for improving and maintain proper ergonomics (Kobayashi, Fisher & Gapp, 2008).

Over the years, 5S has interchangeably been referred to as a philosophy, technique or tool. Kobayashi (2009), established the variations in 5S terminology and practice from research by Osada (1991) and Hirano (1995). The study showed that the variations exists because 5S is recognized as a philosophy in Japanese organizations, while organizations in the United Kingdom (UK) and United States (US) consider 5S as a tool or technique (as cited in Shaikh et al., 2015). According to Osada (1991), 5S is a strategy for achieving cleanliness, orderliness, and discipline in the work environment, whereas Hirano (1995) considered 5S as an industrial method for competitive advantage. Similarly, Omogbai and Salonitis (2017) drew a distinction between the deployment of 5S in Japan and in the West. According to Omogbai and Salonitis (2017), 5S is a strategy for attaining organizational excellence by Japanese companies. Workers are taught 5S as a culture to be practiced within the work environment and in their personal lives. Meanwhile, companies in the UK and US adopt 5S as a tool for workplace organization only.

5S ushered in the industrial revolution in Japanese manufacturing organizations and as such was rapidly adopted in the West (Kanamori, 2016). The perceived benefits from the successful implementation of 5S led to its application being extended across varied sectors such as industrial plants, service providers, educational institutions, and government agencies (Shaikh et al., 2015). Traditionally, the concept of 5S was initially deployed as 3S and 4S by organizations. In recent years, it has been adopted by organizations as 6S, with the last S being safety. However, "despite the wide spread of this technique, researchers and practitioners have had trouble going beyond the simplest form of 5S concept" (Shaikh et al., 2015, p.928).

In the West, 5S is largely considered a housekeeping technique (Becker, 2001, Chandra & Kodali, 1998; Eng & Yusof, 2003; Massey & Williams, 2005; Shamsuddin & Hassan, 2003; Young, 2015). The variations in theory regarding 5S has resulted in differences of how it is practiced in organizations. These variations are further exemplified in the difference that exists between Toyota's and Boeing's practice of 5S. Toyota adopts 5S as a part of its Total Productive System (TPS) embedded in the culture of the organization, whereas Boeing applies 5S as a corporate strategy for attaining and maintaining a universal safety standard. This is achieved by examining each individual job process step-by-step to eliminate activities that are hazard prone (Ansari & Modarress, 1997).

The 5S Components

The acronym of 5S have been translated into English equivalents by Hirano (1995) as sort, set in order, shine, standardize, and sustain. This is the most frequently used and easy to understand equivalents. Other variations include the ONCSD, 5C, and CANDO (Kobyashi, 2009). Table 1 shows the different variations. Throughout this research, the English equivalents of 5S by Hirano was used.

Table 1

5S Components, Equivalents, and Aim

		Other Variations			
Japanese	English 5S	5C[a]	ONCSD[b]	CANDO[c]	Aim
Seiri	Sort	Clean out	Organization	Clean up	Remove unwanted items from the work area
Seiton	Set-in-order	Configure	Neatness	Arranging	Visual workplace – assign every item a place
Seisou	Shine	Clean & check	Cleaning	Neatness	A clean workspace
Seiketsu	Standardize	Conformity	Standardize	Discipline	Standardize and maintain work place procedures and processes
Shitsuke	Sustain	Custom & practice	Discipline	Ongoing improvement	Audit, communicate, and train employees until it becomes a habit

[a] O'hEocha (2000, p. 321). [b] Osada (1991, p. 25-32). [c] Massey and Williams (2005, p. 331).

As indicated in the previous section, the differences in theory, terminology, and translations of 5S have widely influenced its practice. According to Kobayasi et al. (2008), Hirano placed emphases on the first two components of 5S. Every component of

5S relates to each other with *shitsuke* (sustain/discipline) as the core. The relationship between the components are shown in Figure 1.

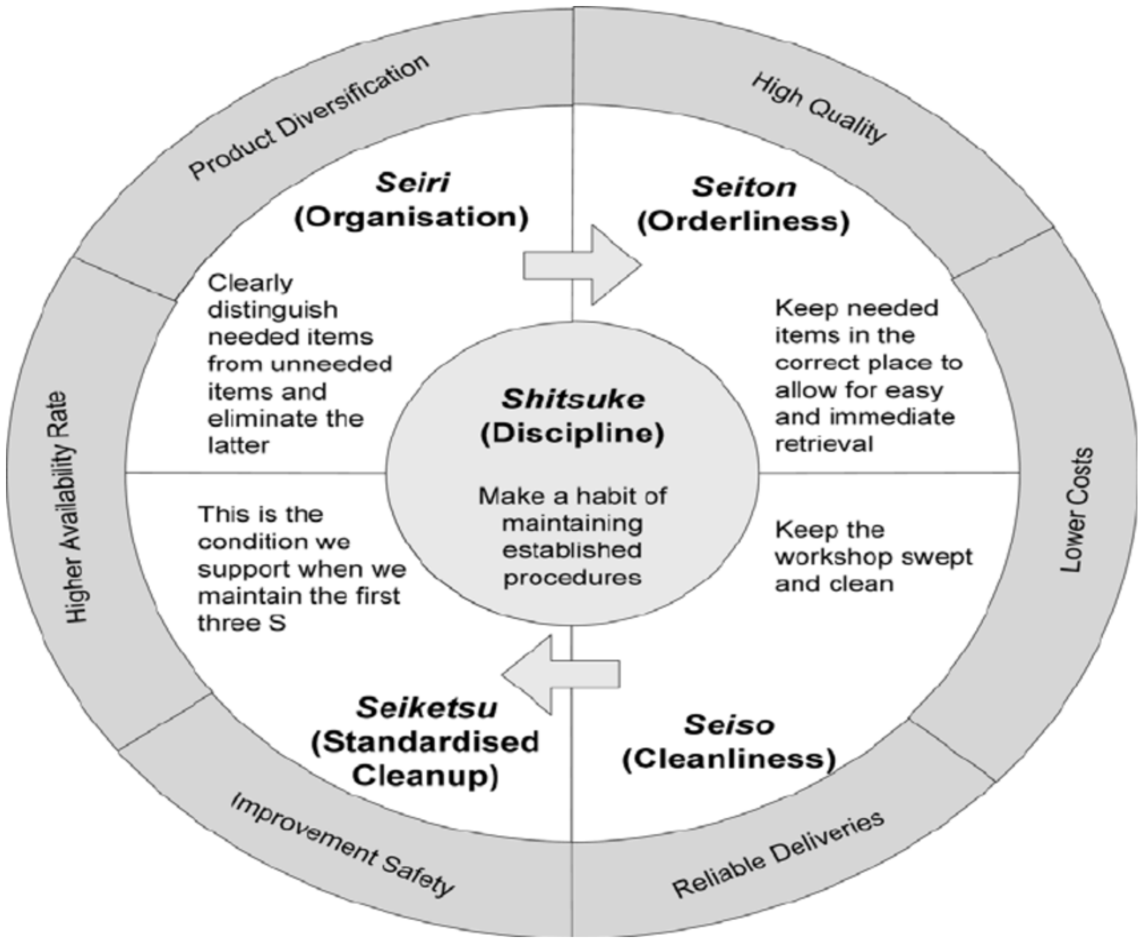


Figure 1. The relationship between 5S components (Hirano, 1995).

Osada (1991), divided the technique into orderliness (*sort and set in order*), cleanliness (*shine*), and discipline (*sustain*). Chapman (2005), agreed that a successful implementation of 5S creates a disciplined, clean and well-ordered work environment. Figure 2 shows the relationship of the components of 5S based on Osada's view. Osada placed an emphasis on the last two components – standardization and discipline (Kobayashi et al., 2008). Hirano's and Osada's translations of the 5S acronyms determined the strategy towards deployment. According to Kobayashi et al. (2008), Osada adopted a bottom-up strategy, whereas Hirano adopted a top-down approach. Strategies for 5S implementation will be discussed in the next section.

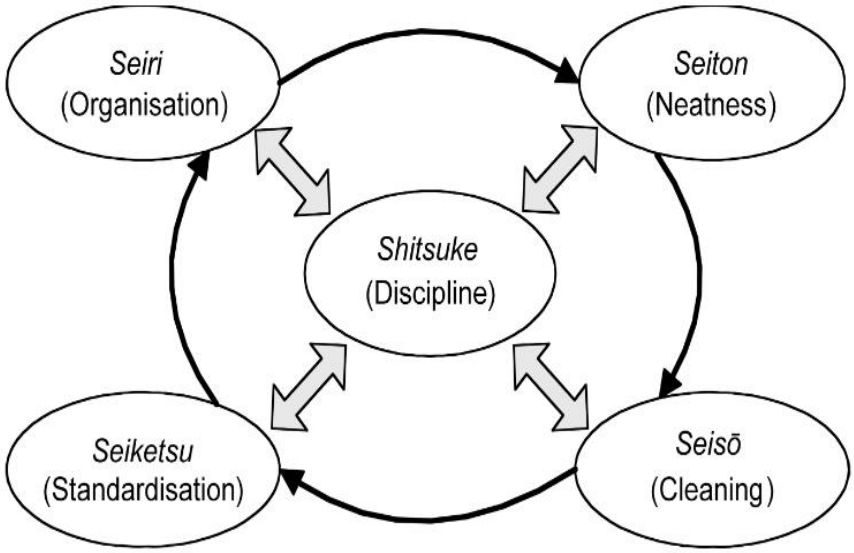


Figure 2. The relationship between 5S (ONCSD) components (Osada,1991).

According to Hutchins (2007), the first phase *sort* is designed to eliminate unwanted or unneeded items from the workplace. The philosophy behind the sort phase is to bring orderliness to the organization. Due to the sorting phase, the efficiency of tool search is improved, operations running time is reduced and a clean workplace is maintained (Sharma & Singh, 2015) According to Chapman (2005), the sort phase ensures that the workspace is freed of extraneous and accumulated items such as clutter – work-in-progress, scrap, documents, packaging material, tools, machinery, equipment, and miscellaneous items.

The second phase *set in order* is for creating a visual workplace – a place for everything and everything in its place. This enables the efficiency in the workflow, improves the ergonomics of the workplace, reduces human motion, and allows for further orderliness after unwanted items have been removed. Needed items are segregated and marked in storage cabinets (Sharma & Singh, 2015). Segregation of items is achieved through shadow boards, color-coding and floor markings (Naqvi, 2013). This provides a clear location for anyone to easily assess working tools. According to Chapman (2005), creating a visual workplace ensures a workplace that speaks without verbal communication. A more visual workplace, reduces the working hours, equipment search time, and ineffective processes or systems (Pentti, 2014).

The third phase *shine* is cleaning of the workplace and equipment. This involves scheduled routine cleaning activities. According to Massey and Williams (2005), these routine cleanups can be done 5-10 minutes per shift. This phase works alongside the concept of Total Productive Maintenance (TPM), which encourages routine checks and regular cleaning of equipment to reduce equipment breakdown. This phase improves safety, working environment, and ensures efficient equipment.

The fourth phase *standardize* defines procedures and processes required for continuous improvements in the workplace (Naqvi, 2013). This phase is regarded as the discipline phase of 5S. According to Massey and Williams (2005), this phase requires the maintenance of the other 3S's by ensuring that employees comply with agreed standards for the workplace. To standardize and sustain workplace procedures and processes, a scheduled audit must be conducted.

The fifth phase *sustain* is focused on the development of habits that sustain the 4S's (Naqvi, 2013). During this phase, 5S is already a culture within the organization, which leads to continuous improvement. This continuous improvement is an offset of *Kaizen*. Kaizen is small incremental improvements over time (Manos, 2007). According to Naqvi (2013), management, along with supervisors and employees, conduct daily, weekly, or twice-a-week meetings to review the 5S's. Audits, communication and trainings are performed continuously in this phase.

5S Implementation Strategy

Organizations have adopted different strategies in the implementation of 5S. The most common strategy is implementing each phase of the 5S sequentially. However, Hirano (1995), in his book *5 Pillars of the Visual Workplace,* suggested the following strategy for 5S implementation: (1) Establish 5S promotion in the organization, (2) Establish 5S promotion plan, (3) Establish 5S campaign materials, (4) In-house education, (5) 5S implementation, and (6) 5S evaluation and follow up. According to Malik (2014), Hirano's strategy required that the simplest methodologies be executed first. The strategies adopted in more recent times in the West is largely linked to Hirano's six-step strategy (Kobayashi, 2009).

Another strategy widely adopted in the West is the Deming's plan, do, check, and act (PDCA) cycle. Sidhu et al. (2013), study is a notable example of applying the PDCA cycle. During the *plan* cycle, data was collected after investigations. In this cycle, training is conducted, and each member of the team is assigned duties, which are displayed on a notice board. In the *do* cycle, 5S phases are implemented in the organization. At the third cycle *check*, evaluations are conducted to determine if 5S is successful and to discover possible areas of improvement. The last phase *act*, the 5S is continuously revisited in the organization and workers are recognized based on their commitment to 5S. Table 2 shows 5S implementation as published in scholarly articles.

Table 2

5S Implementation Strategies

Deming, (1950)	Ho and Cicmil, (1996)	Singh and Ahuja, (2014)	Sari et al. (2017)
1) Plan	1) Get top management commitment and be prepared	1) Announcement of top management's decision to implement 5S	1) 5S Training
2) Do	2) Draw up a promotional campaign	2) 5S training and collection of data	2) Creating 5S team and dividing the task
3) Check	3) Keeping records	3) Establish an organizational structure	3) 5S action
4) Act	4) 5S training	4) Formulate basic 5S policies and goals	4) Continuous improvement
	5) Evaluation	5) 5S plan for deployment	
		6) Feasibility study and its presentation	
		7) Pilot installation	
		8) Plant wide installation	
		9) Progress audit	
		10) 5S certification and award	

As Kobayashi (2009) mentioned, most of the strategies for implementing 5S have evolved from Hirano and Osada. A common factor in each is the need to train the participants about 5S. However, in these strategies, the training is not done at the beginning of 5S implementation. Another factor worth mentioning is these strategies may not have an actual implementation step (Kobayashi, 2009). In this study, 5S was implemented in the surveying laboratory through this three-step strategy. First, conduct ten minutes of 5S training to ensure that the study participants are familiar with their responsibilities, increase involvement, and provide a basic understanding of 5S. Second, implement 5S phases in the laboratory with participants actively involved. Third, conduct an evaluation to ensure that there is a system for continuous improvement. The study's implementation strategy was similar to the PDCA cycle and that of Sari et al. (2017).

The Relationship between 5S and Continuous Improvement Methodologies

Beyond the simplistic application of 5S, it has been described as the foundation of continuous improvement methodologies. Scholars have linked 5S to continuous improvement methodologies such as Total Quality Management (TQM), Total Productive Maintenance (TPM), Workplace Safety Management System, Environmental Management System, Lean, Just-in-Time (JIT), and Six Sigma (Kobayashi, 2009; Ho et al., 1996; Gapp et. al., 2008). However, according to Kumar et al. (2007), improvement methodologies have failed to achieve their strategic goals when applied together because of incompatibility. This is no longer the case as 5S has a relationship with manufacturing continuous methodologies alongside International Organization for Standardization (ISO) systems standards. Furthermore, 5S has been recognized as a strategic platform for managerial decisions needed for developing Integrated Management System (IMS) (Kobayashi et al., 2008). This is depicted in Figure 3.

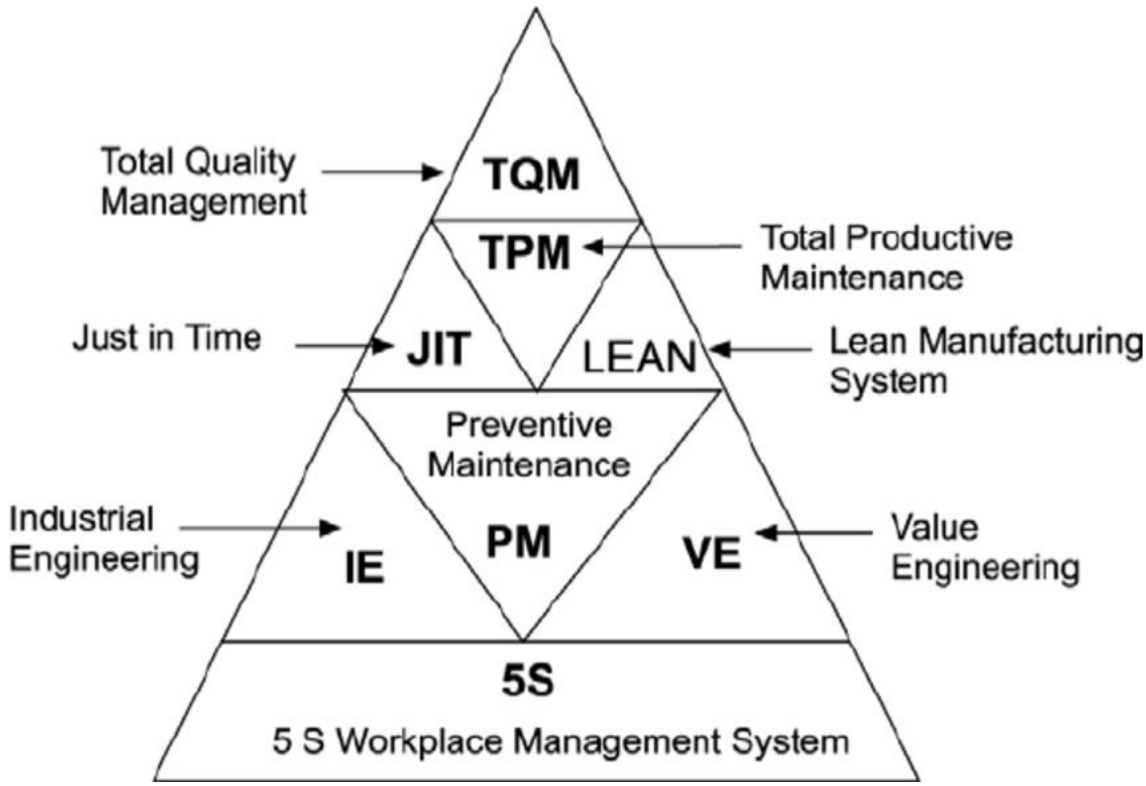


Figure 3. Relationship between 5S and improvement methodologies. Adapted from "Total productive maintenance: Literature review and directions." by I. P. S. Ahuja, and J. S. Khamba, 2008, International Journal of Quality & Reliability Management, 25(7), p. 709-756.

The 5S technique has been described as a foundation and pillar for methodologies such as lean, JIT, and TQM. Because 5S is described as managerial system for promoting quality environment (Ho & Cicmil, 1996), it is a foundation for the successful application of quality circles and TQM. According to Tafreshi and Safavi (2004), an organized workplace is key to the implementation of TQM, ISO, JIT and quality systems. 5S is also considered a foundation for lean because of its ability to eliminate wastes from non-value-added activities or waste from human motion. The implementation of 5S has resulted in reduced travel distance for equipment tool search and other activities.

5S is also considered a part of TPM. Lynch (2000), stated that 5S is crucial for improving workplace ergonomics and autonomous maintenance to keep the workplace environment clean and easily identify hazardous conditions such as oil leaks (cited in Douglas, 2002). This implied that 5S is an integrated aspect of TPM (Bamber et al., 2000). According to Sharma and Singh (2015), 5S must be established before TPM is implemented. In addition, 5S has also been linked to achieving ISO standards such as ISO 9000, 1S0 9001, ISO 14000, and ISO 4001 for environmental standards (Kobayashi, 2009).

The Applicability of 5S in Laboratories

According to Jiménez et al. (2015), 5S has been applied to various kinds of laboratories in various parts of the world. Case studies on the application of 5S in these kinds of laboratories (chemical, educational, pharmaceutical) will be discussed below. This section, reviews case studies of the implementation of 5S in laboratories as a means of attaining industrial standard. In the study, *Implementing the 5S Methodology for the Graphic Communications Management Laboratory at the University of Wisconsin-Stout* (2011), 5S was implemented in the laboratory to provide a more efficient work station layout with organized and labeled storage of items and equipment. The outcome of the study showed that 5S was applicable to a film laboratory. After the implementation of 5S, the GeM lab 130, became well-organized, safer, more efficient, and cleaner. The impact of 5S implementation during the study was determined by photographs.

A study by Chitre (2010), *Implementing the 5S Methodology for Lab Management in the Quality Assurance Lab of a Flexible Packaging Converter* was conducted to organize, clean and manage the laboratory as a means of improving efficiency. The results from this study were measured through before and after pictures that showed improvements in organization of tools, cleaner environment, visual workplace, and storage space utilization. According to Chitre (2010), for the benefits of 5S implementation to be sustained it must be adopted as a part of lean. In addition, 5S was viewed as a housekeeping technique and as such there was low management and employee involvement.

Implementation of 5S in a chemical laboratory at a medical device company was done by Tran (2011). The study was conducted to implement lean six sigma principles for which 5S was a part. The need to re-organize the laboratory to improve workflow was determined. In addition, the laboratory required organization because of the clutter of unwanted supplies. After the implementation of 5S, efficiency and responsiveness were improved, which led to cost reduction. Furthermore, the distance between the workstation and materials were reduced. This caused a reduction in the distance traveled for preparing a solution from 468 feet to 245 feet. The cycle time was also reduced to an average of 30 minutes, which led to an annual labor-saving cost of $2000.

In the study *5S Methodology Implementation in the Laboratories of an Industrial Engineering University School*, 5S was implemented to optimize and improve the safety of university engineering laboratories. Jiménez et al. (2015), justified the selection of an educational laboratory as suitable place for the implementation of 5S based on teaching space for interaction with students, the student productivity, and hands-on industrial experience. As such, the 5S methodology was deployed in four laboratories; Sheet Metal Forming and Cutting, Integrated Manufacturing Systems, Welding, and Metrology, over three months. The outcome of 5S implementation was a 30% reduction in practicums, improved control and maintenance of equipment, no laboratory accidents, reduced inventory and waste, clean environment, well-labeled equipment, and visual controls that communicated deviations or failures. This led to a cost reduction and a 25% increase in available space. According to Jiménez et al. (2015), a new culture of commitment to continuous improvement was created among the participants (faculty, staff, and students) along with a detailed knowledge of available resources in the laboratory. The next section discusses the methods of evaluating the performance of 5S and the method adopted for this research.

Evaluation of 5S

The evaluations and maintenance of current workplace conditions can be equated to the stretching of a rubber band; once it is released, it returns to its original state (Hirano, 1995). Hence, there is a need for measurements to determine 5S performance over time. Performance checks help identify infractions and failures in the 5S deployment (Chapman, 2005). According to Ho and Cicmil (1996), evaluations are important for organizations to keep everyone competing in a friendly way and audit worksheets is one of the easiest ways. Internal audits help measure overall system conditions. The studies of Chitre (2010) and Chi (2011) used before and after photographs to visually measure the performance of 5S. One of the other ways is by using 5S checklists and patrol score sheets (Hirano, 1995).

Additionally, quantitative and financial methods have also been used to also measure the effectiveness of 5S. Quantitative methods include interviews and surveys used to determine participants' perception of the benefits of 5S. However, Kobayashi (2009) claimed that the use of quantitative and financial methods to evaluate 5S performance is ineffective. He recommended that a simple evaluation method should be used for everyone to understand the progress made. This study adopted a quantitative approach to determine the relationship between the dependent variable and the independent variables and the difference before and after 5S implementation. The study *The Relationship of Lean Manufacturing 5S Principles to Quality, Productivity, and Cycle Time* (Lynch, 2005), used a quantitative approach. Pearson's correlation coefficient was used to determine whether a relationship existed between the independent variable (5S) and the dependent variable (productivity, quality, and cycle time).

Benefits of 5S Implementation

The major benefits of implementing 5S include increased productivity, promptness, enhanced confidence, less accidents, less equipment breakdowns or downtimes, increased workspace, improved performance, and reduction in documentation (Baral, 2012), In the study *Implementation of 5s Management Method for Lean Healthcare at a Health Center in Senegal: a Qualitative Study of Staff Perception*, implementation of 5S brought about improvements in the work environment, attitude and behavior of patients and employees, quality of services efficiency, patient-centeredness, and safety (Kanamori et al., 2017). These benefits were determined by interviews with 21 participants regarding their perceived benefits of 5S implementation. In another study by Deshpande (2015), the benefits of 5S implementation included increases in productivity, reduction in equipment search time, reduction in cost and inventory, increase in workspace, well-defined walkways, increased morale, and participation of officers, staff, and workers in continuous improvement.

These are some of the main benefits of 5S implementation from scholarly articles: efficiency (Agrahari, Dangle, & Chandratre, 2015; Chi, 2011), waste reduction (Chi, 2011; Ghodrati & Zulkifli, 2012), equipment efficiency and reduction in equipment search time (Ab Rahman et. al., 2010; Jiménez et al., 2015; Sharma & Singh, 2015), safety (Aziz et al., 2014; Chi 2011; Chitre, 2010; Deshpande et al., 2015), increased workspace and effective utilization of space (Deshpande et al., 2015; Kaushik et al., 2015), product quality (Chi, 2011), and improved working conditions (Borges Lopes, 2015; Ishijima, Eliakimu, & Mshana, 2016; Kaushik, 2015). According to Kobyashi (2009), when organizations practice 5S for an extended period, the benefits tend to differ. A reason for the difference in the benefits may be because of different aims and objectives when deploying 5S. The objectives of each organization at the start of 5S implementation may differ; hence, the difference in actual or perceived benefits. Furthermore, certain barriers can compromise potential benefits. More details on this will be discussed in the next section.

5S Implementation Barriers

Mehral, Attri, and Singh (2015), agreed that the implementation of 5S in an organization is not easy as it entails establishing new cultures, forming new habits, improvement of working conditions, and the participation of every employee. The level of participation of management and employees has been ranked one of the most important barriers in the deployment of 5S in organizations. The lack of motivation or willingness to participate because management or employees do not see 5S as more than a housekeeping tool has hindered the successful adoption of 5S. Hence, the focus on providing training for participants before any 5S activity. Table 3 identifies the barriers to the implementation of 5S in an organization.

Table 3

Barriers to the Implementation of 5S

Barriers	
Lack of top management commitment	Lack of motivation
Financial constraints	Inability to change organizational culture
Lack of awareness of 5S	Non-clarity of organization policy/program
Lack of strategic planning of 5S	Lack of communication
Lack of employee commitment	No proper vision/mission
Resistance to change	Lack of leadership
Lack of cooperation/team work	
Lack of education and training	
Conflict with other quality management systems	

Adapted from “Identification of Barriers Affecting Implementation of 5S” by S. Mehra1, R. Attri, B. Singh, 2015, *International Journal of Advance Research in Science and Engineering*, *4*(1), p. 616-624.

Misconceptions of 5S

The first misconception about 5S is that it is a mere housekeeping tool. According to Chitre (2010), 5S delivers more potential other than being a housekeeping tool. In fact, housekeeping is a spinoff of one of the activities of 5S – *shine*. The potential of 5S is bigger than housekeeping. This is clearly visible based on the relationship of 5S with lean manufacturing methodologies. 5S in most cases is the foundation or pillar of continuous improvement methodologies. The idea that 5S is a housekeeping tool leads to its underutilization, which has a direct impact on the outcome of 5S. In the study conducted by Chitre (2010), participants were unwilling to contribute because they considered 5S a housekeeping tool.

A second misconception is that 5S is a quick fix or a magic wand to immediately solve workplace problems. Indeed, there are significant benefits and changes after the implementation of 5S. However, 5S is a culture change and a continuous improvement methodology. To reap the benefits of 5S, it must be revisited and improved on continuously. According to Chitre (2010), Australian organizations seem to have a fair understanding of the potential of 5S as a continuous improvement tool. Organizations can become easily frustrated in the deployment of 5S. This may be because of slow results, which may lead to reduced involvement from employees, but with the long-term goals in mind, they can strategically achieve the objectives for implementing 5S.

A third misconception is that 5S is just a tool or technique. While this is not a problem, organizations must go beyond this thinking for a change in the organizational culture to be embodied. According to Kobayashi (2009), Western organizations have grasped the importance of the 5S, but have yet to apply it in a holistic way. 5S should be deployed as a philosophy that cuts across the lives of employees or participants. In Japan, 5S is taught as a way of life, which directly impacts education, business, and personal life.

A fourth misconception is the idea that 5S is simple. According to Kobayashi (2009), the oversimplification of 5S causes misunderstandings and underutilization. In the UK and US, 5S is considered nothing more than a technique with no actual implementation phase in their strategy. The over simplification of 5S can lead to misunderstanding between two phases of the 5S. *Seiri* (sort) can easily be confused as *Seiton* (set in order) and vice versa.

Lastly, a prevalent misconception is the impression that only one or two phases of 5S can be implemented. In the West, and in a few organizations in Japan, implementation stops at the first 3S. According to Kobayashi (2009), partial application of 5S is due to certain operational objectives. However, to get targeted goals, every phase should be fully implemented.

Summary of Literature Review

In summary, it has been shown from the literature review that there is no general definition of 5S and the technique may be oversimplified or complicated. This gives room for shortcomings in the 5S technique as it is often underutilized in the workplace. However, the benefits of the implementing 5S is one that makes it worthwhile, especially for organizations where management and employees are involved, thereby making it an organizational culture. This chapter justifies a context for 5S implementation in the laboratory based on anticipated benefits from its application in similar laboratories. It provides a strategy for the adoption of 5S and the need for performance measurement, which may often be overlooked.

Methodology

Introduction

The surveying laboratory in Figure 4 is used mainly for three purposes: (a) as a computer station, (b) storage of surveying equipment for outdoor practicums, and (c) competitions, and calculations. The purpose of the study was to implement 5S in a surveying laboratory and determine participants' perceptions of its impact in the laboratory. Are there improvements in safety, effectiveness, equipment search time, laboratory working environment, and workspace? The study area was the surveying laboratory in the Engineering and Biological Sciences building of WKU. The laboratory was selected through faculty consensus. Although the laboratory adheres to basic safety regulations, the study intended to further enhance its performance through implementing 5S technique to improve laboratory effectiveness. This study provided a roadmap for other laboratories to follow within an educational system. In addition, it was also a participatory study that involved the participation of laboratory users in creating a better work environment and knowledge on the concept of 5S.

Research Design

This study used a pre-test, post-test experimental design. A structured survey instrument was used to obtain data from study participants to investigate the perceived current state of the laboratory and the perceived improvements after 5S implementation. To improve participation, the participants were taken through a brief (ten-minute) 5S training.

Research Participants

The study population were students who had previously enrolled for surveying laboratory practicums and were currently enrolled during the semester of 5S implementation. In addition, the study population included an instructor actively involved in the frequent use of the surveying laboratory. The pre-test survey was conducted a week before implementing 5S and the post-test survey was conducted immediately after the standardize phase. The survey participants were selected through convenience sampling. Creswell (2014), defined convenience sampling as a sampling method that relies on convenience and availability of the respondents to take part in the study. This method was suitable for this study because the study population was a naturally formed group and the study participants, which are students, were volunteers.

5S Survey Instrument

The survey instrument was dispersed by hand and through the Qualtrics Survey software. Qualtrics Survey Software was used to create a survey and collect data based on the following metrics: perceived safety, perceived efficiency, perceived working environment, perceived laboratory workspace, and perceived equipment search time. Qualtrics Survey Software is used to create, distribute, and analyze online surveys. The survey instruments consisted of two open-ended questions and 16 closed-ended questions. The instructor and students were asked to rate their perceptions of the selected performance metrics on a Likert scale with 1 representing strongly disagree (SD) and 5 representing strongly agree (SA). A ranking of not applicable (N/A) was included for questions that participants may have considered inapplicable/irrelevant to the survey laboratory. The survey was distributed through emails and by hand to the study participants pre and post-implementation. According to Visser, Krosnick, and Lavrakas (2000), surveys are used to assess whether the changes over time in a dependent variable can be predicted by prior levels of an independent variable. In this study, the survey was used to determine whether the dependent variables of the study, which were efficiency, safety, equipment search time, laboratory environment climate, and workspace, were affected by the independent variable 5S. Refer to Appendix C for the structured survey.

Implementation of 5S

Implementation of the five phases of 5S in the surveying laboratory at WKU was done within six weeks. Appendix D shows the timeline for implementing 5S. 5S was carried out in the laboratory to standardize the laboratory and increase laboratory effectiveness.

Seiri/Sort. After a scheduled meeting with faculty to discuss areas of improvement and problem areas in the surveying laboratory, the sort phase was started. Unwanted items in the laboratory were red tagged (Appendix F) and moved to a red tag area. Red tags were used to identify items and equipment which were considered scrap, old, not needed, extra or defective. The items in the red tag area consisted of extra and broken equipment, equipment belonging to other laboratories, and equipment that had become obsolete. There were also several empty storage cartons, which were immediately disposed of thereby freeing up shelve and floor space, as shown in Figure M3. The items in the red tag area were in the holding area for a week and items that remained unused during this period were moved into external storage or disposed of. After which, the laboratory was cleaned. This phase increased the laboratory workspace, shelves space, and improved workflow. The process owners and instructor were active participants in this phase.

Seiton/Set-in-order. This phase was used to organize and create a visual workplace in the surveying laboratory. Other than the sustain phase, which is a continuous ongoing process, the set-in-order phase was one of the longest phases in the implementation of 5S in the surveying laboratory. During this phase, items were allocated a position in the storage cabinets. The tools were arranged according to the frequency of use and proximity to the workstation. The workstation, which was clustered with gadgets as shown in Figure M4, was cleared up. During this phase, items from the top of three storage cabinets were assigned new locations. This phase improved efficiency, safety, and reduced equipment search time. Equipment blocking the fire alarm were relocated, items in storage cabinets were arranged in a synchronized manner, storage cases were stored close to their equipment, and documents were filled and sorted.

Seiso/Shine. According to Chitre (2010), the shine phase is a process-oriented phase that involves probing the root cause of waste and dirt using the collected data. At this phase, a fishbone diagram in Appendix K was used to probe the root cause of inefficiency and dirt in the surveying laboratory. A weekly cleaning schedule was developed based on the practicum groups as shown in Appendix G. The entire laboratory workspace was cleaned, which included equipment, tools, and workstation areas/floor. This phase improved the laboratory environment and safety.

Seiketsu/Standardize. Standard operating procedures (Appendix I) and laboratory rules and regulations (Appendix J) were established in the surveying laboratory. Floor tapes and corner markers were used to indicate movable equipment, corners of storage cabinets, exit/aisle ways, and hazardous areas. In addition, the storage cabinets were color-coded (Red, White, Blue, Yellow, Green, and Orange) for easy retrieval of tools. Using the checklist in Appendix H, the previous three steps were revisited – sort, set-in-order, and shine. The checklist showed the need for more color coding of the storage cabinets and for an updated safety data sheet. Areas in need of improvements were noted and addressed.

Shitsuke/Sustain. An audit (Appendix L) was conducted two weeks after the standardize phase to examine the progress in maintaining 5S as a culture in the laboratory. A visual board was created with pictures showing the pre and post 5S implementation to remind and motivate every one of the benefits of 5S. Posters were also strategically positioned to instill a culture of 5S. 5S is a continuous improvement tool, and as such, the participants should strive to retain the set standards that were documented during the standardize phase. Each student was responsible for their toolbox, cleaning of workstation after use, and return of equipment to labelled locations.

Experimental Design

The research sought to implement 5S in a surveying laboratory and to assess its benefits. To determine the perceived benefits, a pre-test, post-test experimental design approach was selected. The experiment conducted a pre-test through a structured survey instrument to determine the laboratory's current state based on the performance metrics before 5S implementation. After 5S was implemented, a post-test survey was conducted to investigate the perceived benefits of implementing 5S. Actual measurements of equipment search time and laboratory workspace were taken pre and post 5S implementation.

Variables

This study identified the independent variable as the 5S technique while the dependent variables of the study were efficiency, safety, equipment search time, laboratory environment climate, and workspace.

Efficiency. This referred to the improvement in workplace practices and time required to complete a practicum. The efficiency of the laboratory was determined by study participants' perception of the time required to conduct a practicum and the actual time it took to complete the practicum before and after 5S implementation.

Equipment search time. The equipment search time in this study referred to the time required to find equipment tools in minutes during a practicum. The search time was measured pre and post implementation of 5S in the laboratory. The data collected through the questionnaires were analyzed to determine the study participants' perception of equipment search time.

Laboratory workspace. According to Srinivasan (2012), increase in laboratory workspace is an indicator of a successful 5S implementation. The laboratory workspace was measured in square footage (ft^2) before and after the implementation of 5S. Also, study participants' perceptions of the increase in workspace was collected.

Safety. This referred to a workspace with safety equipment, instructions, and behaviors that are beneficial to the participants and prevent health hazards. The data from the questionnaire was analyzed to investigate if there was an increase in the perception of safety post implementation of 5S.

Laboratory working environment. In the book, *Guide to Human Factors and Ergonomics* by Helander, an ambient environment is described as the influence of environmental variables on the operator. In the case of the laboratory, it is the influence of a clean and organized workplace on the students and faculty (2015, p. 12). The study measured participants' perception of the current laboratory working environment pre and post 5S implementation.

Experimental Instrument

The following materials and instruments were used to successfully implement 5S in the surveying laboratory:

Camera. This was used to capture the progress of 5S to create visual representation of previous and current state.

Floor tapes/labeler/corner markers. These were used to mark and identify equipment or items in cabinets. In addition, they were used as markings for direction, hazardous areas, safety equipment for example fire extinguisher and exit routes.

Red tags. The red tags were used as a visual sorting tools to identify unwanted items in the workplace and determine the course of action required for such an item. (Appendix F)

Cleaning supplies. These were used to ensure that the laboratory stayed clean and dust free.

File folders/file box. File box was used to store files in the laboratory.

Hooks. To hang safety jackets.

Fishbone diagram. The fishbone diagram, also called Ishikawa is a cause-and-effect diagram, was used to find the root cause of inefficiency and dirt in the laboratory.

Experimental Procedure

The experimental procedure for the research follows:

1. The study participants were surveyed using a pre-test survey instrument in Appendix C. This was done to ascertain the perceived current state of the laboratory by the study participants.
2. The workspace area, practicum completion time, and equipment search time were measured before 5S implementation.
3. A training video was included at the end of the pre-test survey. Participants were introduced to the 5S technique by the process owner. The process owner expected each student to have fundamental knowledge about 5S to take part in its implementation.
4. The five phases of 5S was implemented in the laboratory as shown in Appendix D
5. After the fourth phase of 5S implementation, the study participants were surveyed using the post-test survey instrument in Appendix C. This was to determine the perceived benefits of implementing 5S in the survey laboratory.
6. Measurements were taken of the workspace, practicums completion time, and equipment search time after 5S implementation.

Data Collection

Data was collected through surveys to assess the participants' perception of the benefits of 5S implementation in the laboratory. The survey was a structured questionnaire that included the same questions asked in the same order pre and post 5S implementation. In addition, equipment search time was recorded, and usable workspace in square footage pre and post 5S implementation.

Data Analysis

This study investigated perceived efficiency, perceived workspace, perceived equipment search time, perceived working environment, and perceived safety pre and post 5S. The pre-test and post-test survey included 18 questions, two open-ended and 16 close-ended Likert scale items. The two open-ended questions consisted of questions regarding "last four digits of WKU ID" and "semester of first/last experience in the surveying laboratory". These data were used to determine if the participants met the inclusion criteria of having laboratory experience *both* before and after the implementation of 5S.

The close-ended questions contained questions pertaining to perceived efficiency, workspace, equipment search time, working environment, and safety. A one-tailed paired t-test was conducted using Minitab to compare the pre-test and post-test survey scores. The significance threshold was set at an alpha of 0.05 and a confidence interval of 95% was assumed for the analysis. Efficiency was measured pre and post 5S by six items (Questions: 1- 3, 7, 14, and 15) and was inclusive of equipment search time. Workspace was measured by three items (Questions: 2, 4, and 16) on the survey instrument and the square footage pre and post-5S. Equipment search time was measured by two items (Questions: 14 and 15) and the time required to find items during a practicum. Laboratory work environment was measured by eight items (Questions: 2, 6, and 8 - 13). Safety was measured by seven items (Questions: 4, 9, and 12). The results helped to determine the impact of 5S on efficiency, workspace, equipment search time, working environment, and safety.

Threats to Validity

The threats to validity of the study includes:

1. Space – The surveying laboratory is limited in space and this may have had a direct effect on the study hypothesis and 5S implementation.

2. Funding – Limited or insufficient funding for the materials needed during the implementation of 5S in the laboratory. As such, the study utilized existing storage cabinets, created labeling tools, and other useful items within the laboratory.

3. Availability of students over a period – All study participants may not have been available to take a post-test. To account for this, the survey was conducted during a semester to ensure that students enrolled to take laboratory classes remain the same. Each participant was given a participant ID to match the pre-and-post survey responses.

4. 5S training – A ten-minute training was conducted prior to implementing 5S. This may cause the participants to provide responses that agree with the objectives of

5S. To avoid familiar responses based on the training, the post-test was conducted six weeks after the training.

5. History – The 5S phases were scheduled to take place within six weeks. During this period, events may occur that can affect the experiment. To monitor the progress to ensure that no changes occur that may alter the outcome. A 5S audits was conducted.

Summary

The success of 5S was determined by conducting a pre-test and post-test survey based on the study's performance metrics. The improvements in efficiency and laboratory working environment, safety, increase in workspace, and reduction in equipment search time determined whether 5S was successful or not. Since 5S is a continuous improvement methodology, the participants were encouraged to retain the 5S culture to remain standardized.

Results and Discussion

The purpose of this pre-test, post-test experimental study was to implement 5S in the surveying laboratory and investigate whether 5S influences perceived effectiveness, workspace, equipment search time, working environment, and safety.

Overall Findings

Participants. A total of 43 participants responded to the pre-test survey and were assessed for eligibility. Of the 43 participants who completed the questionnaire, only 14 participants fulfilled the inclusion criteria of having laboratory experience *both* before and after the implementation of 5S. The post-test survey was completed by 18 participants. After excluding the students who did not meet the inclusion criteria, a sample of 10 participants who were involved in both tests remained. The inclusion criterion was restricted to participants who had used the laboratory in the previous semester, were currently using the laboratory during 5S implementation, and participated in the pre-survey. The results of the survey are shown in Appendix N.

Analysis. Table 4 provides the descriptive analysis and paired t-test results of five tests performed to investigate the study's hypothesis. The increase in performance metrics of the study (dependent variables) were determined through a one-tailed paired t-test on Minitab.

Table 4.

Descriptive analysis and paired samples t-test results for perceived efficiency, workspace, equipment search time, work environment, and safety pre-/post-test

			Pretest		Posttest					
Variable	*N*	*df*	*M*	*SD*	*M*	*SD*	95% Upper Bound for μ_difference	*t*	*p*	*r*
Efficiency	10	9	4.00	0.47	4.63	0.40	-0.41	-5.21	0.00028	0.62
Workspace	10	9	3.50	0.81	4.77	0.39	-0.86	-5.73	0.00014	0.50
Equipment Search Time	10	9	4.00	0.53	4.75	0.54	-0.31	-3.14	0.006	0.00
Work Environment	10	9	3.57	0.69	4.65	0.33	-0.62	-5.04	0.00035	0.25
Safety	10	9	3.86	0.53	4.63	0.39	-0.46	-4.48	0.001	0.32

$\alpha = .05$

Hypothesis 1

Hypothesis 1: After implementing 5S, efficiency will increase.

Efficiency in the previous chapter was defined as equipment search time and workplace practices. To determine the impact of 5S on efficiency, a paired t-test was performed to compare pre-test and post-test survey scores. The null hypothesis was $H_{Eb} = H_{Ea}$ while the alternate hypothesis was $H_{Ea} > H_{Eb}$. 5S led to a perceived increase in efficiency as the post-test mean score was higher in comparison to the pre-test mean score. This comparison was statistically significant ($t = -5.21$, $p < .001$) (see Table 4). Thus, the null for hypothesis 1 was rejected. Results from the efficiency scale suggested that participants perceived there was an improvement in the time spent finding items during practicums and in workplace practices after 5S implementation.

Hypothesis 2

Hypothesis 2: After implementing 5S, the workspace will increase.

The paired t-test determined whether 5S had an impact on the perceived laboratory workspace. In addition, the workspace area was measured pre/post 5S implementation exclusive of fixtures and storage cabinets. 5S led to a perceived increase in workspace as the mean post-test score is higher in comparison to pre-test mean score. From the analysis shown in Table 4, there was a significant difference in the mean scores from 3.50 to 4.77 with a p-value < 0.001. At a level of significance .05, the null for hypothesis 2 was rejected.

The storage cabinets attached to the walls of the laboratory made it difficult to save workspace. However, after 5S, 15.35 ft2 workspace was freed up. To calculate this, the laboratory was divided into two sections as shown in Table 5. Pre 5S implementation, the total area of the workspace was 231.77 ft^2. Post 5S implementation, the total workspace area was 247.12 ft^2. There was a 6.6% increase in workspace after 5S.

Table 5

Recovered Workspace by Sections

Section	Recovered Space (ft^2)
A	4.25
B	11.10
Total	15.35

Hypothesis 3

Hypothesis 3: After implementing 5S, equipment search time will reduce.

The equipment search time was defined as the time required to find equipment and the perceived improvement in finding equipment by the participants in the laboratory pre/post 5S. To determine the impact of 5S on equipment search time, the percentage decrease in equipment search time was determined and a paired t-test was conducted. 5S led to a perceived reduction in equipment search time as the post-test mean is greater in comparison to pre-test mean. This comparison was statistically significant ($t= -3.14$, $p < .05$). This indicated that participants considered the time required to find equipment had improved post 5S.

The storage cabinets for the separate groups were labeled, color-coded, and equipment were arranged in a synchronized manner based on the frequency of use. Pictures and equipment layouts were included in the cabinets. The actual time required to find equipment over the course of a week's practicum by each group (Green, Red, Orange, Yellow, Blue, and White) was recorded a week before 5S and two weeks after 5S. There was an average of 11.8% reduction in equipment search time post 5S. See Table 6. Thus, the null for hypothesis 3 is rejected.

Table 6.

Equipment search time based on a week's practicum using one equipment

Day	*N*	Pre 5S (Sec)	Post 5S (Sec)	Time saved
Monday[a]	15	232	205	27
Monday[b]	12	179	166	13
Wednesday[b]	15	241	201	40

[a]=Lab. [b]=Sections.

Hypothesis 4

Hypothesis 4: After implementing 5S, working environment will improve

5S led to a perceived positive increase in laboratory working environment as the post-test mean score was higher in comparison to pre-test mean score. The reported average after the implementation of 5S was significantly higher than before 5S was implemented ($t = -5.04$, $p < .001$). Thus, the null for hypothesis 4 is rejected. Results from the test, observation, and feedback from participants showed that there was a perceived improvement in the laboratory's working environment.

Hypothesis 5

Hypothesis 5: After implementing 5S, safety will improve

5S led to an increase in perceived workspace safety as the post-test mean score is higher in comparison to pre-test mean score. The reported mean scores show a significant increase in the perceived safety at a significance level of less than .05. The null for hypothesis 5 is rejected. Results from the survey indicates that implementing 5S in the surveying laboratory had a positive impact on perceived safety.

Discussion

Summary

This was a pre-test, post-test experimental study conducted to implement and investigate the perceived impact of 5S on efficiency, workspace, equipment search time, working environment, and safety in the surveying university. The study began in the spring semester of 2018 and lasted for six weeks (January 22nd – March 6th). Three practicum classes were enlisted as a part of the study. However, due to the inclusion criteria, the study was limited to 10 participants. As such the results cannot be generalized to all educational laboratories. At the start of 5S event, the participants viewed a short five-minute 5S training video, which was included at the end of their pre-test survey. Over the course of six weeks, 5S was implemented in the surveying laboratory. At the end of the 5S event, a post-test survey was conducted by hand and through the Qualtrics Survey Software. Participants were presented with the survey instruments during a surveying class. The study's performance metrics were tested using five hypotheses. The results of the study may serve as a guiding framework for improving efficiency, workspace, equipment search time, working environment, and safety in other university laboratories.

Analysis

Results showed that there was a perceived improvement in laboratory efficiency. Efficiency was measured as improvements in the time required to find equipment in the laboratory and improvements in laboratory practices. Feedback from speaking to students and safety inspectors showed that the laboratory was better organized after 5S event making it easier to find required equipment. The results of the survey also showed the perceived efficiency to be statistically higher. The study aligns with results from the research by Kanamori et al. (2016) and Ashraf (2014) that 5S implementation led to the reduction in equipment search time and increased efficiency.

Results showed there was both a perceived and actual increase in the workspace. However, the layout of the laboratory may have limited the recovery of unusable workspace. Irrespective, the results showed that post 5S, the workspace was indeed increased from 231.77ft^2 to 247.12 ft^2 which is a 6.6% increase. The 5S event resulted in a recovery of more workspace, aisle ways, and shelve space. The study by Srinivasan (2012) indicated that implementing 5S reduced floor utilization by 22%. Another study by Ashraf et al. (2017) showed that post 5S, 310.1 square feet was recovered.

Results showed that after implementing 5S there was both a statistically significant perceived improvement and actual improvement in the equipment search time. More precisely, an average of 11.8% reduction in equipment search time was recorded. The study by Ashraf et al. (2017), shows that implementing 5S in a food and beverage industry led to the shortening of equipment search time.

Results showed that the participants perceived significant improvements in work environment and safety due to 5S. The work environment was kept clean before practicums, a cleaning responsibility sheet was created, and clusters of junk on the workstation was eliminated. Implementing 5S in the surveying laboratory helped improve working environment and safety. This supports the study by Kanamori et al. (2016), which led to fewer unwanted items, clean, orderly environment, and improved labeling and directional indicator resulting in an improved work environment. In another study by Singh and Ahuja (2014), safety was improved because of 5S.

Limitations

The study's limitation included the time frame of implementing 5S. 5S was implemented in the laboratory within six weeks. Sustaining of 5S requires a longer period and as such this study may not be able to highlight the long-term benefits of 5S. Congruent with the study by Srinivasan (2012), although surveys were conducted a month after the 5S event, bias may have developed due to the 5S training and the anticipated changes. In addition, based on the surveying laboratory's layout, a few major changes were made with regards to the actual workspace. Also, the surveying laboratory is unique compared to other laboratories in terms of a clean working environment. See Appendix K. 5S would need to become part of the lab culture to maintain an improved working environment. There may be a need for a different approach for other laboratories.

Recommendations for Sustaining 5S in the Laboratory

To sustain the results of the study, which is the goal of a 5S, a post-5S training and audit should be conducted. At the start of a new semester, where there may be new students who may not have taken part of the 5S event, there is a need to conduct a training to ensure that 5S remains a culture. As mentioned in the study, a training was conducted pre 5S, but no training was conducted post 5S. The process owner encouraged the instructor to give a brief post-5S training. After a poster indicating that the surveying laboratory was a 5S area was put up, a student approached the process owner and asked what 5S was. This may be the reaction of future students who would be making use of the surveying laboratory. Hence, the need for constant training and reinforcement.

An audit should be continuously carried out post 5S to sustain the results achieved. The first audit is shown in Appendix L and was conducted two weeks after the 5S event. As it was the first audit, it may have higher scores than usual. This audit was conducted by the instructor and supervised by the process owner to avoid bias. As discussed with faculty, a major issue may be in maintaining the changes made in the laboratory. However, the willingness of faculty to maintain 5S as a culture in the laboratory may be indicative of the audit score. This can only be determined over a period. Hence, the need to carry out 5S audits and revisit 5S activities.

Suggestions for Future Studies

A longitudinal study should be conducted with a larger number of participants to improve the validity of the results. To ensure that the survey responses are without bias, a pre-test could be conducted with a control group and a post-test survey can then be conducted with a treated group. To take this a step further, both a pre/post-test conducted with a control group and a pre-test/post-test conducted with a treated group for comparison and to ensure the validity of data. This would also ensure that the study participants are unaware of whether they are the control or the treated group to eliminate bias from responses. In this instance, ANOVA would be recommended for data analysis.

In addition, further post-5S training should be included in any 5S studies. Also, for future studies that need to improve safety, 6S could be considered rather than 5S.

Conclusion

The results analyzed from the study supports the stated hypotheses in the Introduction. 5S was successfully implemented in the surveying laboratory at WKU to improve efficiency, workspace, equipment search time, work environment, and safety because of the active involvement of faculty. Literature reinforces the need for active management involvement for the successful implementation of 5S (Chitre, 2010; Douglas, 2002; Naqvi, 2013). The results from the study proved that 5S implementation within a university laboratory for standardization and to provide students with an industrialized experience is justified. These findings suggest that 5S can be successfully implemented in other academic laboratories, but may require a different plan. Since maintaining 5S, having a clean workspace, and clear aisle ways was an important factor for the surveying laboratory, the focus was on creating audit forms and checklists to reinforce these characteristics and revisit the various phases of 5S. To encourage active participation of students in future 5S events in the surveying laboratory, frequent training should be conducted.

APPENDIX A: IRB Approval

WKU

INSTITUTIONAL REVIEW BOARD
OFFICE OF RESEARCH INTEGRITY

DATE:	October 25, 2017
TO:	Mercy Ebuetse, B.Eng
FROM:	Western Kentucky University (WKU) IRB
PROJECT TITLE:	[1147044-1] Implementation of 5S at a Surveying Laboratory In Western Kentucky University
REFERENCE #:	IRB 18-147
SUBMISSION TYPE:	New Project
ACTION:	APPROVED
APPROVAL DATE:	October 25, 2017
REVIEW TYPE:	Exempt from Full Board Review

Thank you for your submission of New Project materials for this project. The Western Kentucky University (WKU) IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a project design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received Exempt from Full Board Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the project and insurance of participant understanding followed by an *implied* consent form. Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the consent document.

Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All UNANTICIPATED PROBLEMS involving risks to subjects or others and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office. Please use the appropriate reporting forms for this procedure. All FDA and sponsor reporting requirements should also be followed.

All NON-COMPLIANCE issues or COMPLAINTS regarding this project must be reported promptly to this office.

This project has been determined to be a Minimal Risk project.

Please note that all research records must be retained for a minimum of three years after the completion of the project.

If you have any questions, please contact Paul Mooney at (270) 745-2129 or irb@wku.edu. Please include your project title and reference number in all correspondence with this committee.

APPENDIX B: IRB Approved Consent Form

INFORMED CONSENT DOCUMENT

Project Title: Implementation of 5S at a Surveying Laboratory in WKU
Investigator: Mercy Ebuetse, WKU Engineering & Applied Sciences
mercyakunna.ebuetse142@topper.wku.edu

You are being asked to participate in a project conducted through Western Kentucky University. The University requires that you give your agreement to participate in this project.

You must be 18 years old or older to participate in this research study.

The investigator will explain to you in detail the purpose of the project, the procedures to be used, and the potential benefits and possible risks of participation. You may ask any questions you have to help you understand the project. A basic explanation of the project is written below. Please read this explanation and discuss with the researcher any questions you may have. You should keep a copy of this form for your records.

1. **Nature and Purpose of the Project:** As part of the requirement of the fulfilment of a degree in the school or engineering and applied science, the research is carried out to implement 5S in the surveying laboratory at Western Kentucky University and to assess the impact of the implementation on the laboratory efficiency and safety, reducing equipment search time, improving working environment, and workplace space.

2. **Explanation of Procedures:** You are requested to complete a brief questionnaire that will be conducted pre and post 5S implementation that should take approximately 10 minutes.

3. **Discomfort and Risks:** There are no anticipated risks or discomforts from the research but rather benefits for individuals/organization undertaking the survey.

4. **Benefits:** Participants are expected to gain knowledge about 5S and the required skills to work in a professional environment by standardizing the surveying laboratory and improving its ergonomics through the implementation of 5S.

5. **Confidentiality:** The survey is anonymous. No private information will be used in the research. Your pre and post results will be linked through the last four digits of your WKU ID.

6. **Refusal/Withdrawal:** Refusal to participate in this study will have no effect on any future services you may be entitled to from the University. Anyone who agrees to participate in this study is free to withdraw from the study at any time with no penalty.

You understand also that it is not possible to identify all potential risks in an experimental procedure, and you believe that reasonable safeguards have been taken to minimize both the known and potential but unknown risks.

Your continued cooperation with the following research implies your consent.

THIS PROJECT HAS BEEN REVIEWED AND APPROVED BY
THE WESTERN KENTUCKY UNIVERSITY INSTITUTIONAL REVIEW BOARD
Paul Mooney, Human Protections Administrator
TELEPHONE: (270) 745-2129

INSTITUTIONAL REVIEW BOARD WKU APPROVED

APPENDIX C: 5S Survey

English (US) ▼

Informed Consent

5S Survey

Dear Participants,

I am a graduate student in the School of Engineering and Applied Science at Western Kentucky University (WKU), Bowling Green. I am currently doing a research on implementation of 5S at a surveying laboratory in WKU. The purpose of the study is to implement 5S in the surveying laboratory and to determine its perceived benefits. You will be required to participate in a pre and post test survey. Please be assured that your responses will be kept completely confidential.

This survey should take you about 10 minutes. You have the right to withdraw at any point during the study, for any reason, and without any prejudice.

If you have any questions regarding the survey or this thesis research, please contact Mercy Ebuetse (mercyakunna.ebuetse142@topper.wku.edu/ 812-560-2191) or the Thesis Chair, Dr. Mark Doggett (mark.dogget@wku.edu / 270-745-6951). Your participation in this research is greatly appreciated.

Mercy Ebuetse
WKU

Mark Doggett, PhD
Western Kentucky University
2109 College Heights Blvd.
Bowling Green, KY, 42101

Last 4 digits of WKU ID

In what semester and year was your first experience with the surveying laboratory?

This section is to determine the current state of the laboratory based on the selected performance metrics of the study. Choose the option that best answers each question. Where the questions are not applicable, choose N/A.

Equipment are in clean working condition

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly agree
- Not applicable

I can complete the assigned labs efficiently in this space

- Strongly Agree
- Disagree
- Neutral
- Agree
- Strongly Agree
- Not applicable

Laboratory procedures are documented

- Strongly Agree
- Disagree
- Neutral
- Agree
- Strongly Agree
- Not applicable

The laboratory workspace is safe for movement

- Strongly Agree
- Disagree
- Neutral
- Agree
- Strongly Agree
- Not applicable

Safety instructions are available to each student

- Strongly Agree
- Disagree
- Neutral
- Agree
- Strongly Agree
- Not applicable

Safety standards in the laboratory are enforced

- Strongly Agree
- Disagree
- Neutral
- Agree
- Strongly Agree
- Not applicable

Safety problems in the laboratory are quickly resolved

- Strongly Agree
- Disagree
- Neutral
- Agree
- Strongly Agree

- Not applicable

Safety equipment and personal protective equipment are available in the laboratory

- Strongly Agree
- Disagree
- Neutral
- Agree
- Strongly Agree
- Not applicable

The laboratory is clean before use

- Strongly Agree
- Disagree
- Neutral
- Agree
- Strongly Agree
- Not applicable

Student and Faculty participate in cleaning the laboratory after use

- Strongly Agree
- Disagree
- Neutral
- Agree
- Strongly Agree
- Not applicable

The working surfaces are free of unused items

- Strongly Agree
- Disagree

- Neutral
- Agree
- Strongly Agree
- Not applicable

The top of storage cabinets are free of unused materials

- Strongly Agree
- Disagree
- Neutral
- Agree
- Strongly Agree
- Not applicable

Cleaning supplies are available

- Strongly Agree
- Disagree
- Neutral
- Agree
- Strongly Agree
- Not applicable

Tools and laboratory supplies are properly stored in labeled locations

- Strongly Agree
- Disagree
- Neutral
- Agree
- Strongly Agree
- Not applicable

Required items for laboratory tasks are found in a timely fashion

- Strongly Agree
- Disagree
- Neutral
- Agree
- Strongly Agree
- Not applicable

The workplace is adequate for the lab assignment

- Strongly Agree
- Disagree
- Neutral
- Agree
- Strongly Agree
- Not applicable

Block 1

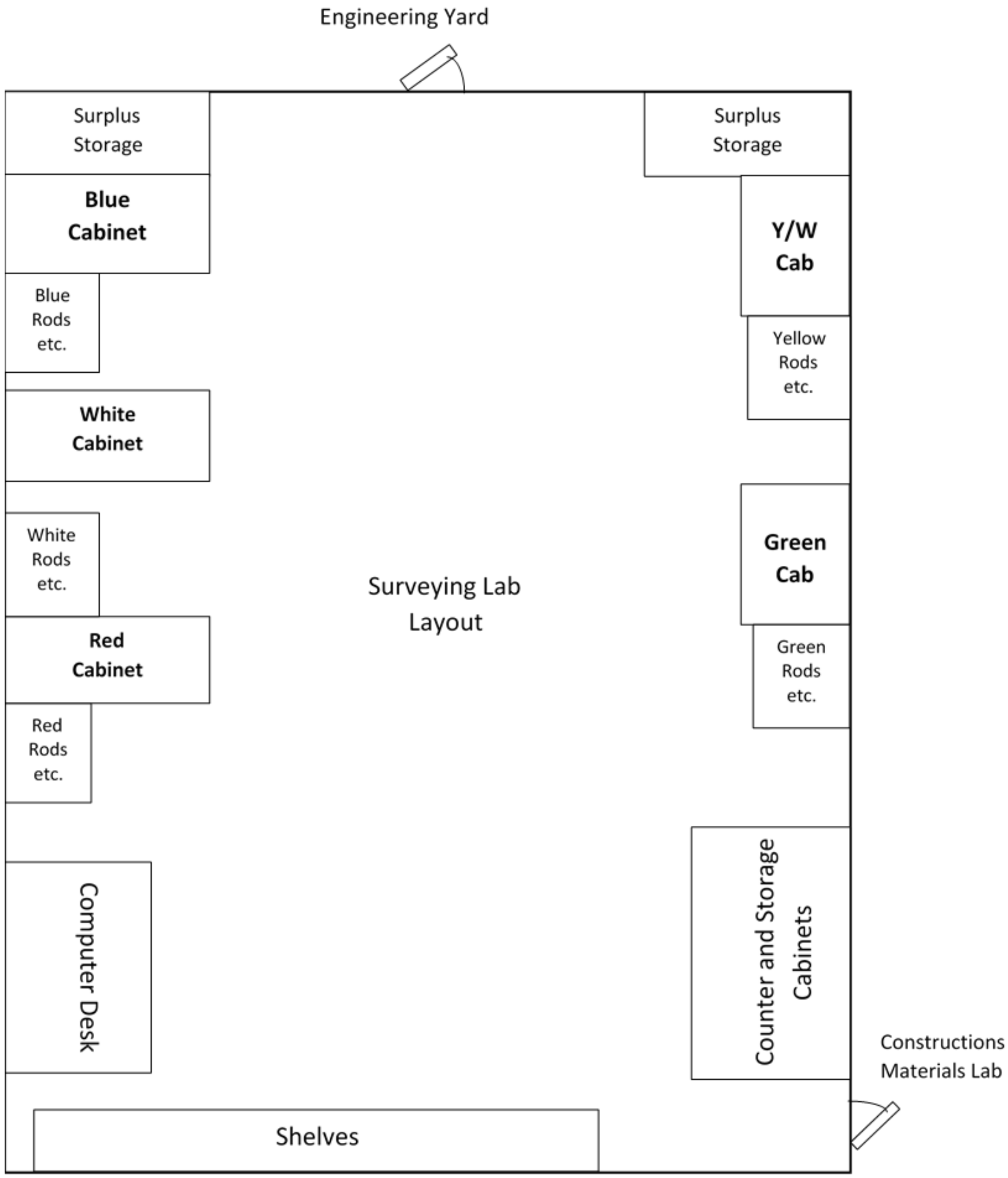
Please watch this short 5S training video. The successful implementation of 5S begins here. A submit button will appear after the video ends. Thank you.

5S Training Video - https://youtu.be/WU8dO5NM9Qw

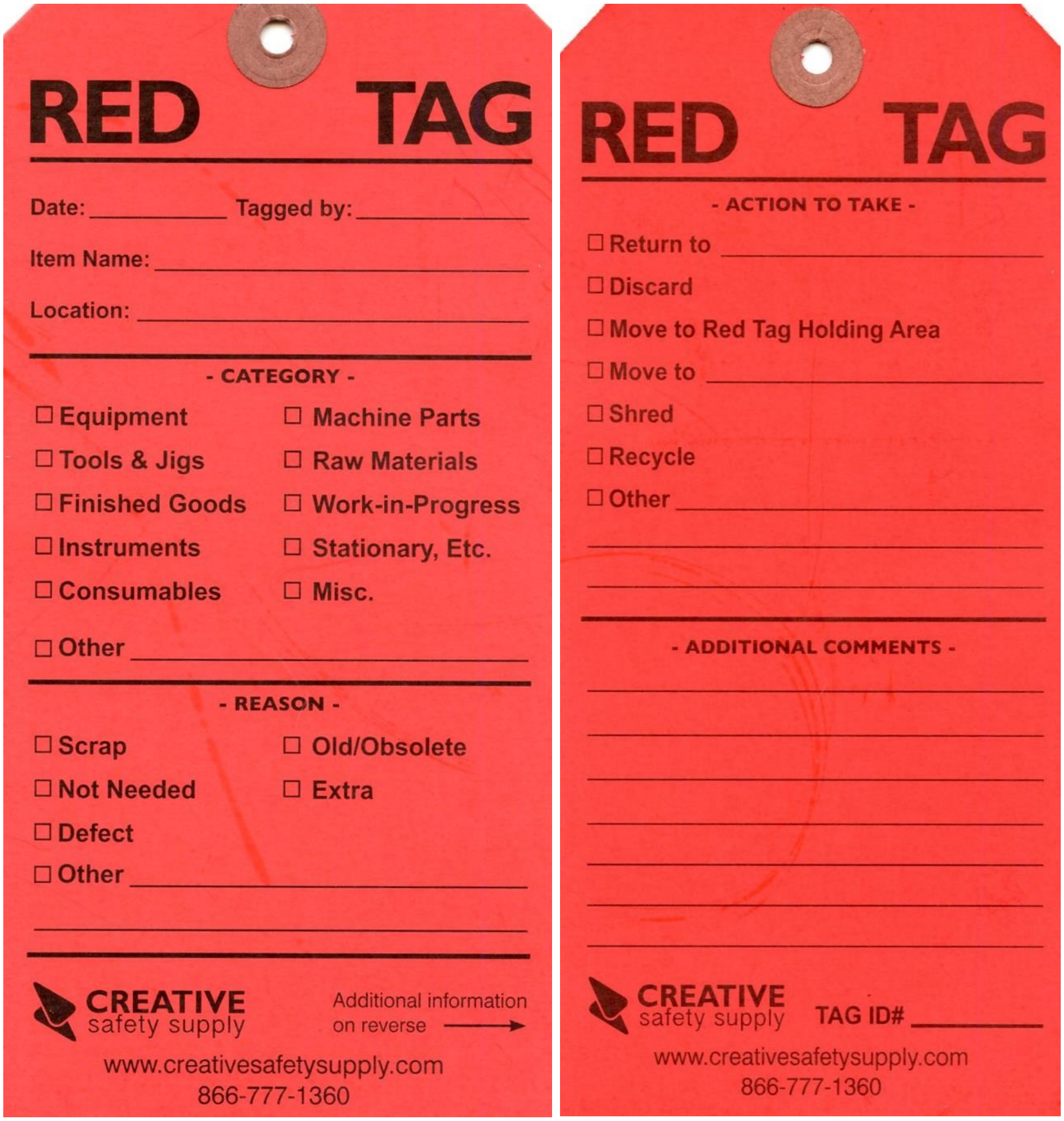
APPENDIX D: Experiment Timeline

Task	Action	Participants	Period
Pretest/Training	Measure perception Observe workspace Explain 5S technique	Process Owner, Instructor, and Students	2 weeks
Sort	Move unwanted and unfrequently used equipment and items to red tag area Find root cause of dirt and clean workspace	Process Owner and Instructor	2 Days
Set-in-Order	Everything has a place. Label items. Create a future state visual map	Process Owner	5 Days
Shine	Inspect laboratory and clean hidden areas Clean equipment and workspace	Process Owner and Students	2 Days
Standardize	Revisit sort, set-in-order, shine phase Establish laboratory rules Color coding	Process Owner and Instructor	2 Days
Post-test	Measure perception Observe workspace	Process Owner, Instructor, and Students	2 weeks
Sustain	5S posters and pre and post 5S pictures Conduct a 5S audit Training Maintain standards	Process Owner, Instructor, and Students	2Days

APPENDIX E: Surveying Laboratory Layout



APPENDIX F: RED TAG



RED TAG

Date: ____________ Tagged by: ____________

Item Name: ____________

Location: ____________

- CATEGORY -

☐ Equipment ☐ Machine Parts

☐ Tools & Jigs ☐ Raw Materials

☐ Finished Goods ☐ Work-in-Progress

☐ Instruments ☐ Stationary, Etc.

☐ Consumables ☐ Misc.

☐ Other ____________

- REASON -

☐ Scrap ☐ Old/Obsolete

☐ Not Needed ☐ Extra

☐ Defect

☐ Other ____________

CREATIVE safety supply

Additional information on reverse →

www.creativesafetysupply.com

866-777-1360

RED TAG

- ACTION TO TAKE -

☐ Return to ____________

☐ Discard

☐ Move to Red Tag Holding Area

☐ Move to ____________

☐ Shred

☐ Recycle

☐ Other ____________

- ADDITIONAL COMMENTS -

CREATIVE safety supply

TAG ID# ____________

www.creativesafetysupply.com

866-777-1360

APPENDIX G: Weekly Cleaning Assignment

Department Surveying Laboratory__________

Checked By ______________________________

Date ________________________

Area/Item	Work Description	Frequency Wk. 1	Wk. 2	Wk. 3	Wk. 4	Wk. 5	Comments
Shelves	Clean the shelf						
	Arrange equipment in assigned position						
Computer Desk/shelf	Clean computer						
	Remove papers from the desk						
	Clean the shelf						
	Arrange software/ manuals in assigned position						
Red/White/Blue /Yellow/Green cabinets	Place equipment in assigned positions						
	Clean cabinet						
Surplus Storage	Arrange safety vests						
Counter top/Storage Cabinet	Clean the counter top						
	Remove items from counter top						
	Place equipment in assigned positions						
	Clean cabinet						
Trash	Empty trash can						
	Place trash can in assigned location						
Cleaning Supply	Inspect cleaning supplies						
	Place cleaning supplies in assigned location						
Laboratory Floor	Inspect floor for grease and oil						
	Vacuum lab floor						

APPENDIX H: Evaluation

Department	Surveying Laboratory			
Checked-by	Tyler Baker			
Date	2/21/2018			
S/N	5S Activities	Check		Comment
		Yes	No	
	Sort			
1	There is no excess equipment	✓		Based on our Knowledge
2	Top of cabinets are free from items and equipment	✓		3 out of 5 are free. No adequate storage for cer-item
3	The counter top and computer table are free of unwanted items	✓		
4	The aisle is free	✓		
	Set-in-Order			
1	Every item is labeled	✓		
2	Items are visible in their stored location	✓		
3	Related items are stored in the same location	✓		
4	Items are easily retrieved and stored	✓		
	Shine			
1	Weekly cleaning exercise is conducted	✓		lab groups assigned
2	The laboratory is free from grease and oil	✓		
3	Cleaning supplies are available	✓		
4	Everyone is actively involved in cleaning	✓		
5	Hidden areas and foot mat are clean	✓		
	Standardize			
1	There are established laboratory rules	✓		
2	There are standard operating procedures	✓		
3	There are floor markings and color-coded cabinets	✓		more color-coding on cabinets needed
4	There is a safety manual	✓		need to update
5	There is a responsibility/cleaning schedule	✓		

APPENDIX I: Standard Operating Procedure

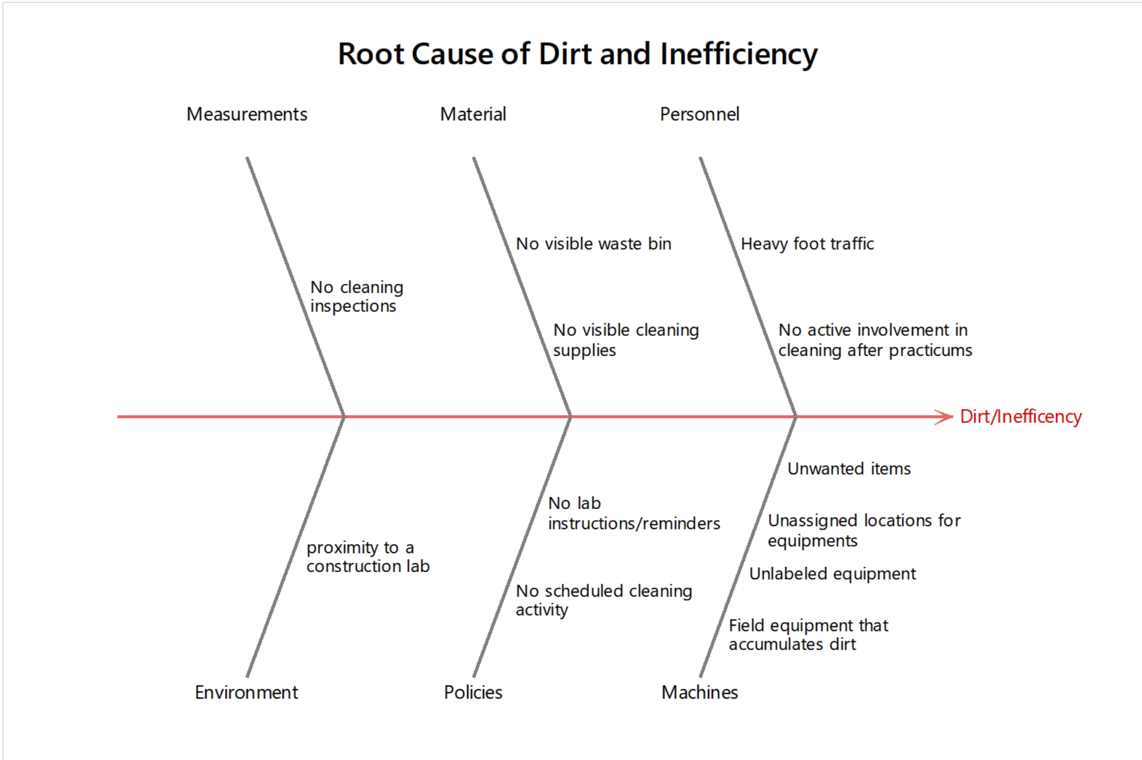
Standard Operating Procedure	
Surveying Laboratory Practicums	
Task	Laboratory Practicums
Sub-Process	
Date	Feb 2, 2018
Time Required:	
Frequency:	Weekly
Safety:	Safety vests
Responsibility	Instructor/Student
Process steps:	**Instructor/Students** Step 1: Pick equipment from storage cabinets Step 2: Pick up vest Step 3: Report to field location Step 4: Conduct Lab Step 5: Record field notes in field book Step 6: Proceed to lab for calculations **Instructor** Step 7: Check Calculations **Instructor/Students** Step 8: Clean up

APPENDIX J: Laboratory Rules and Regulations

Laboratory Rules and Regulations

1. The computer table and counter top should be clean and free of items.
2. Report all injuries to instructor. Do not work with open cuts. A band aid will be provided to you.
3. The equipment in the surveying laboratory are expensive and if unsure of how to use them, notify the instructor before proceeding.
4. If you break any equipment notify the instructor and do not throw away anything that is broken.
5. Always have equipment in line of site.
6. Know the location of the exit and fire alarm.
7. Return equipment to designated locations in the lab.
8. Safety vest must be worn at all times outside the lab.
9. Do not take equipment for personal use unless you have the permission of your instructor.
10. Handover equipment batteries to instructor when leaving the lab.
11. Never fool around in the lab. Horseplay and pranks are strictly prohibited in the lab.
12. Equipment with spikes should be carried with points to the ground. The point should never be above your waist.

APPENDIX K: Fishbone Diagram



APPENDIX L: 5S Audit Form

5S Audit Form

AREA: Surveying Lab **DATE:** 3/5/2018 **AUDIT BY:** Tyler Baker

5S	S/N	Description	Rating: **Very Good** *Perfect condition*	**Good** *1-2 problems*	**Ok** *3-4 problems*	**Bad** *5-6 problems*	**Very Bad** *Above 7 problems*
			0	1	2	3	4
Sort	1	There are no unneeded equipment	0				
	2	There are no unneeded items on the countertops	0				
	3	The aisle is free	0				
	4	Top of storage cabinets are free of clutter		1			
	5	Is there a procedure (red-tag) for eliminating unwanted items from the lab	0				
		Total Score	1				
Set-in-Order	6	There is an assigned location for every item	0				
	7	Every item is in a labeled location		1			
	8	Frequently used items are easy to retrieve	0				
	9	Items are visible in their stored location	0				
	10	Related items are stored in the same location	0				
		Total Score	1				
Shine	11	Weekly cleaning exercises are conducted		1			
	12	Counter tops and equipment are clean and free of debris	0				
	13	Instructors and students are actively involved in keeping the lab clean	0				
	14	The laboratory floor is free from dirt, grease, oil, and hazardous substances	0				
	15	Cleaning supplies are readily available	0				

		Total Score	1				
Standardize	16	Standard operating procedure is established and followed	0				
	17	Safety data sheet is up-to-date	0				
	18	Responsibility/cleaning schedule is up-to-date	0				
	19	Floor markings, color coded cabinets, and signage are visible in the lab	0				
	20	There are established laboratory rules and regulations	0				
		Total Score	0				
Sustain	21	Everyone is involved in maintaining 5S in the lab	0				
	22	Instructor participates in weekly/monthly 5S audits	0				
	23	5S results and posters are displayed for everyone to see	0				
	24	Everyone is trained on their responsibility in maintaining 5S	0				
	25	Established standards are maintained to ensure continuous improvement	0				
		Total Score	0				

APPENDIX M: 5S Implementation Photos

Seiri/Sort Phase

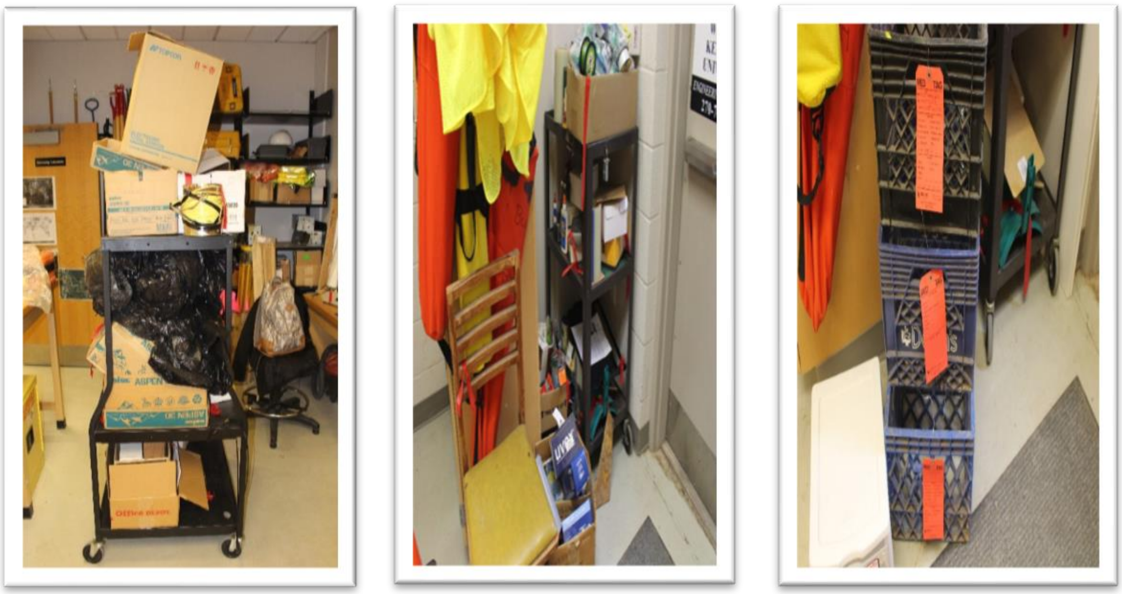


Figure M1. Empty cartons and Red Tag Area

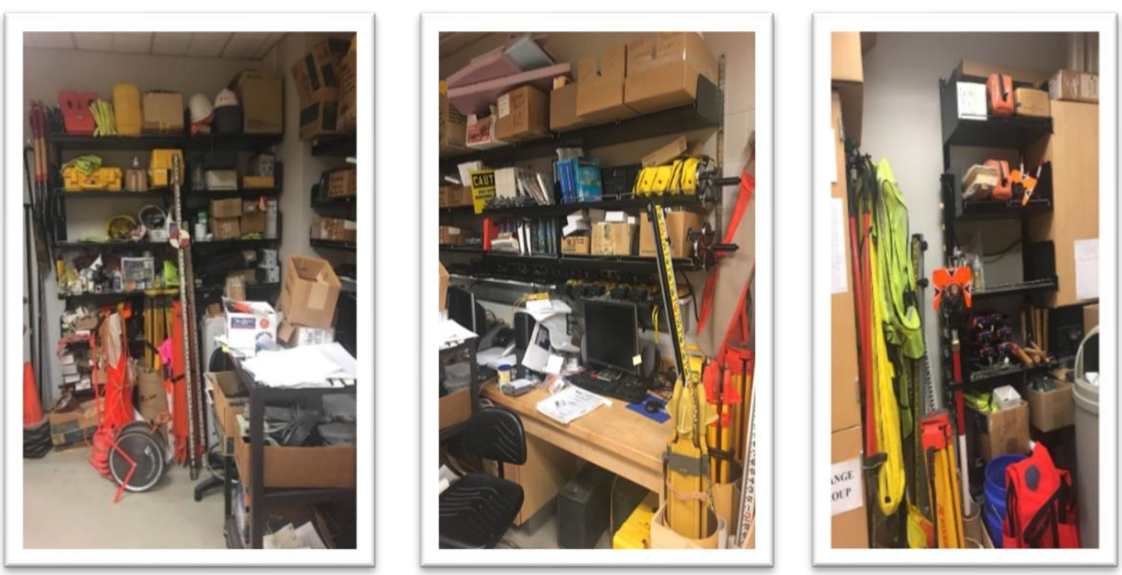
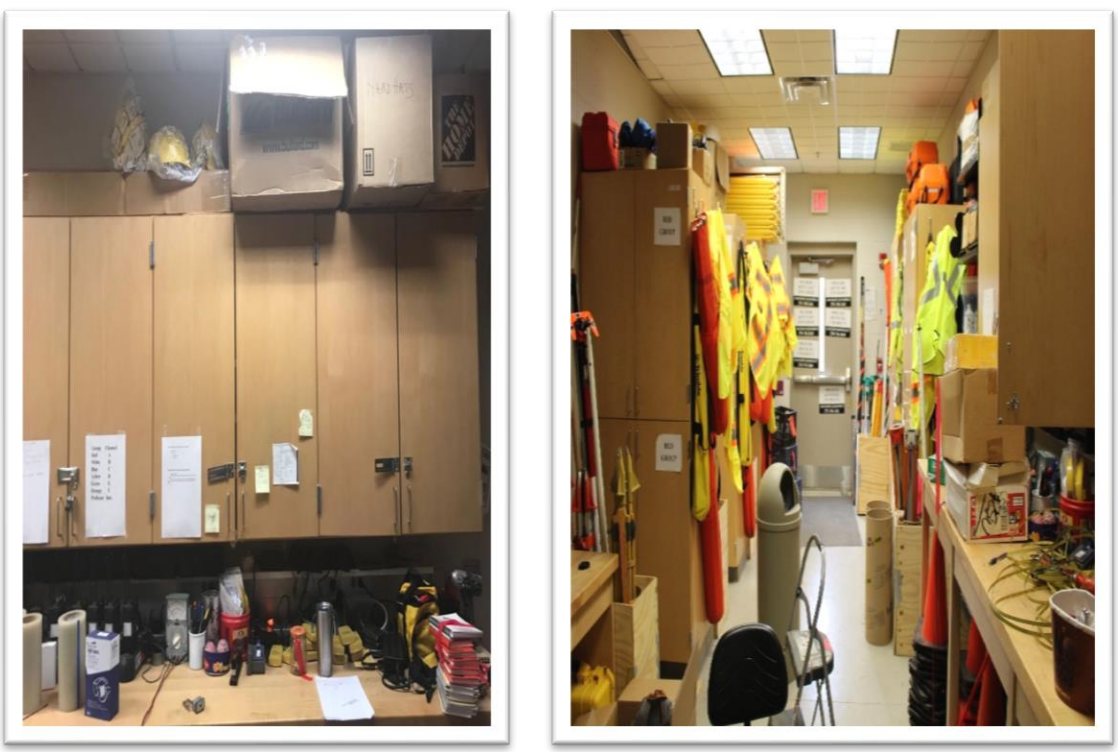


Figure M2. Before 5S Sort Phase

Figure M3. After 5S Sort Phase

Seiton/Set-in-order Phase



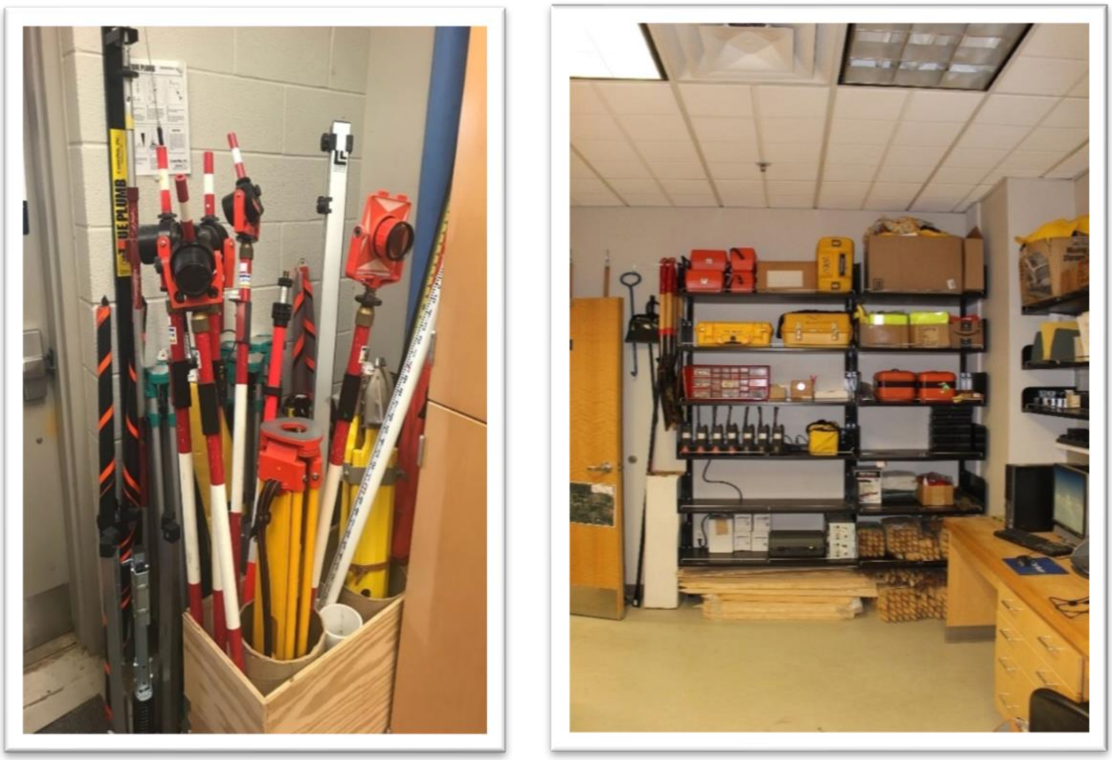
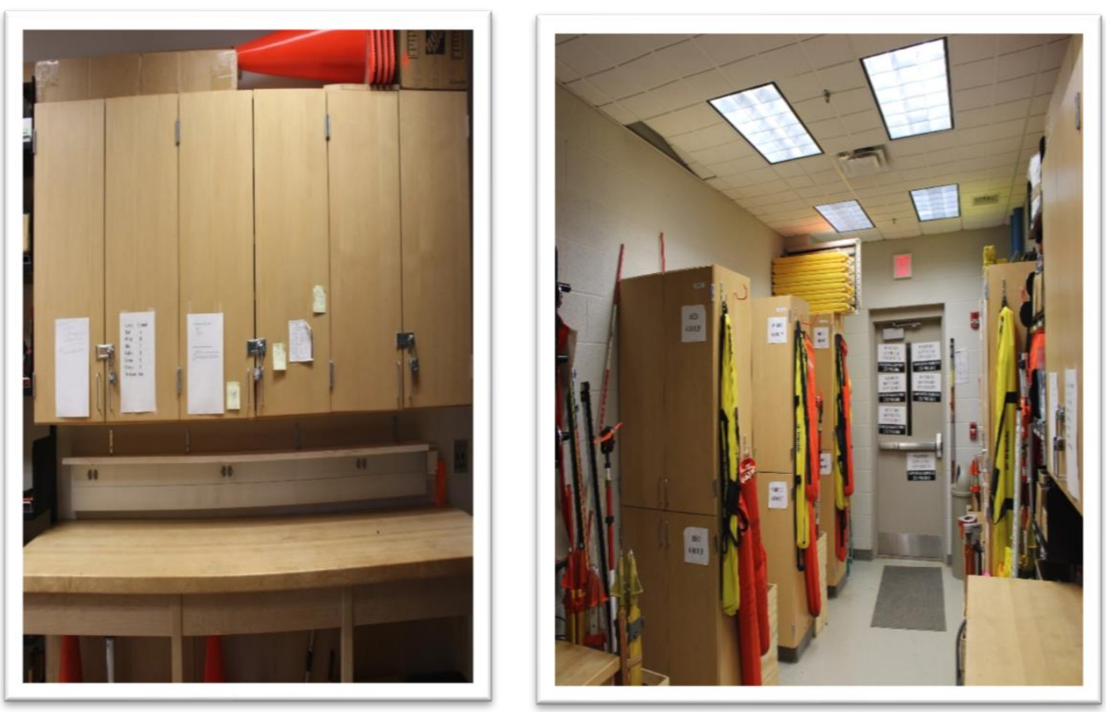


Figure M4. Before 5S Set-in-Order Phase



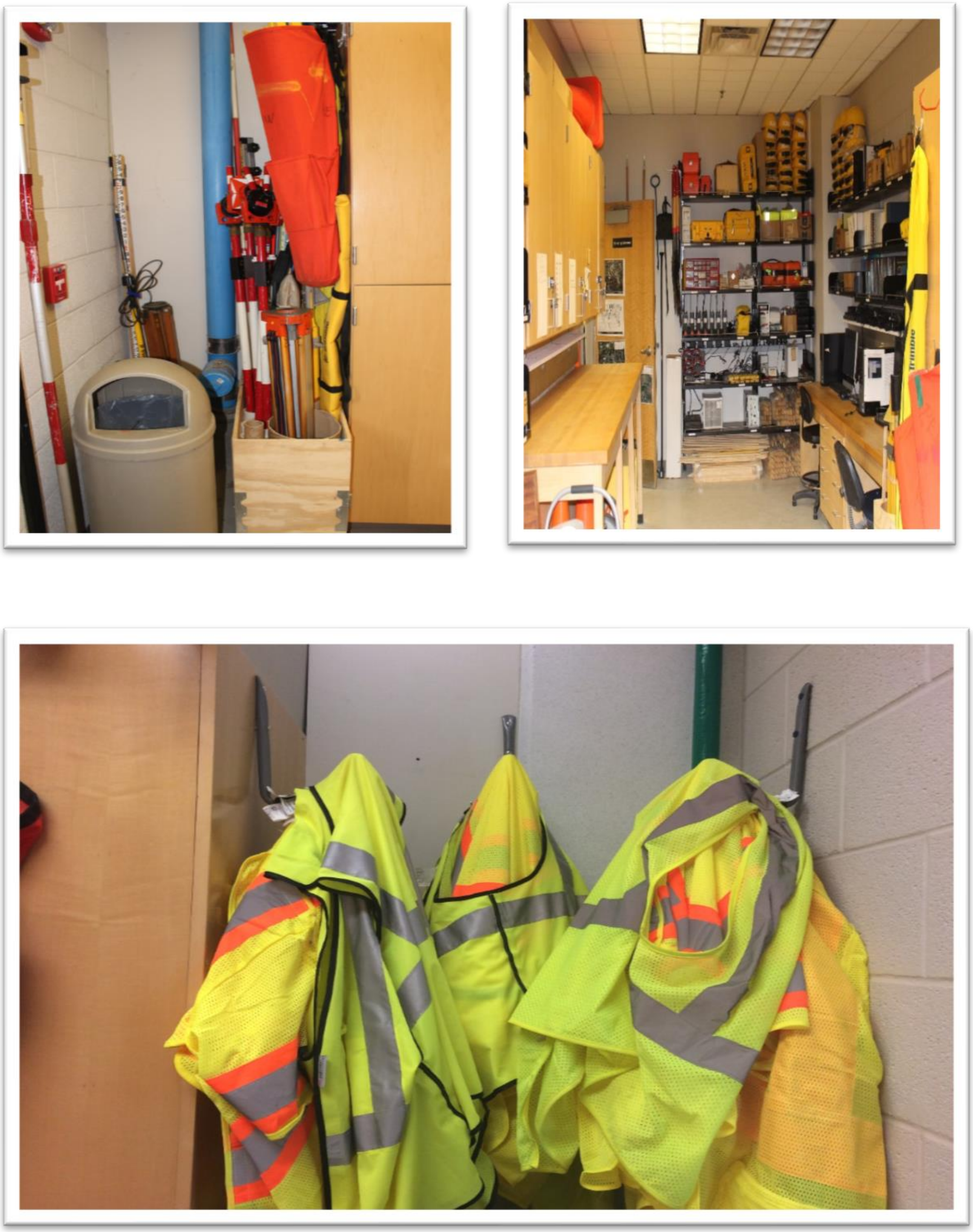


Figure M5. After 5S Set-in-Order Phase

Seiso/Shine Phase

Figure M6. Before 5S Shine Phase

Figure M7. After 5S Shine Phase

Standardize Phase

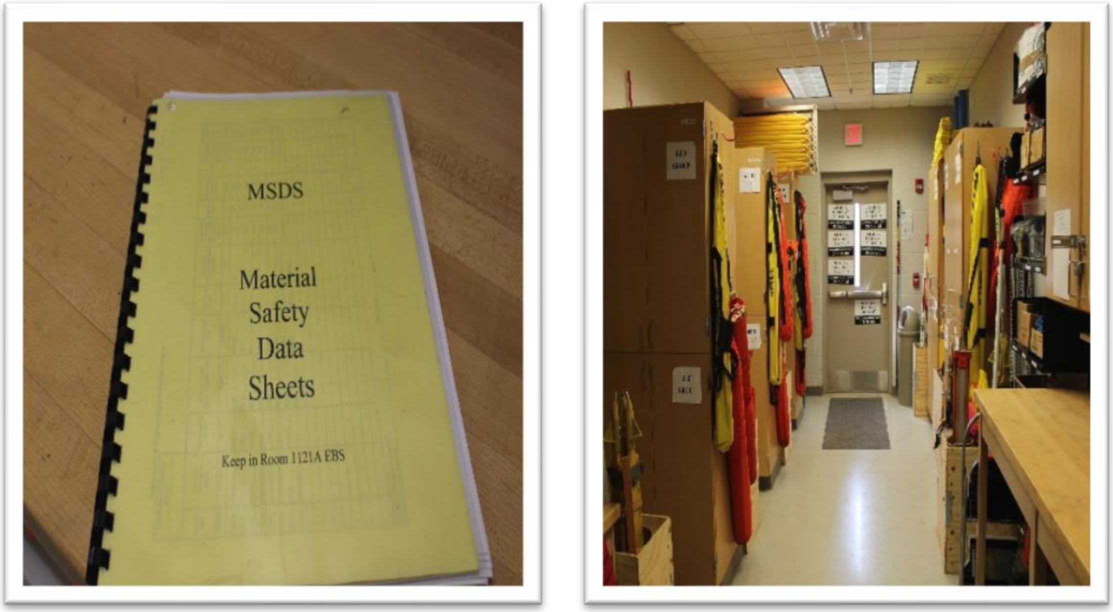


Figure M8. Before 5S Standardize Phase

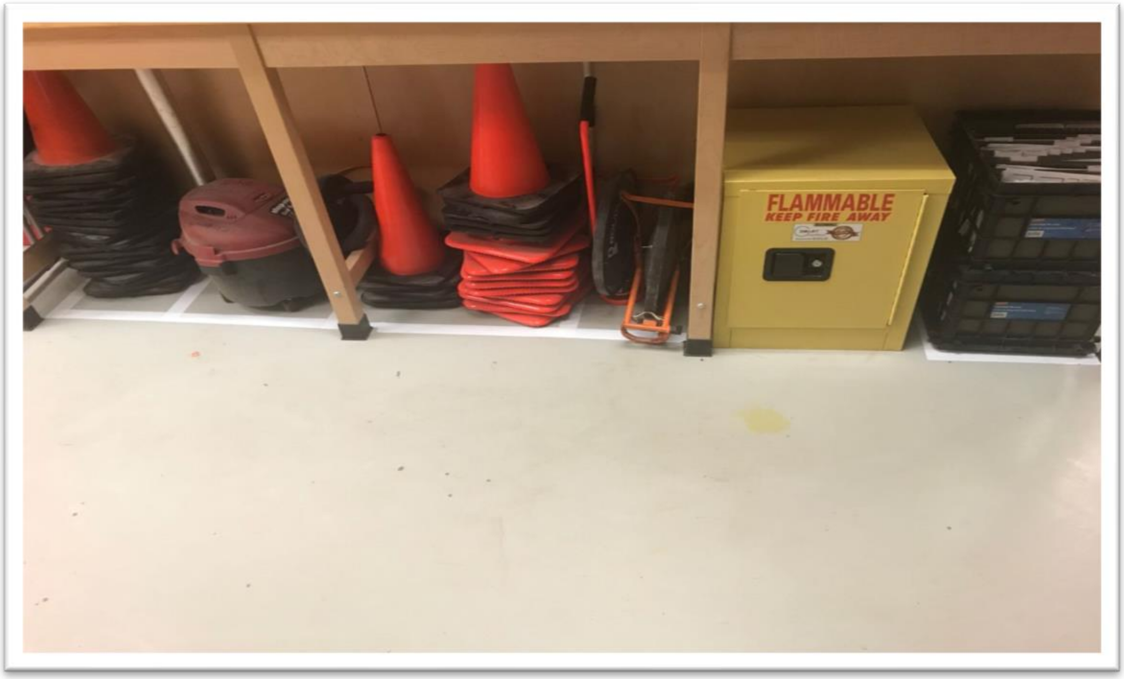


Figure M9. After 5S Standardize Phase

Sustain Phase

Figure M10. After Sustain Phase

APPENDIX N: Survey Results

Table N1.

Pre-/post-test survey results for perceived efficiency of the surveying laboratory

Subscale	Pre 5S	Post 5S
	3.67	5.0
	4.17	4.67
	4.17	4.83
	4.00	4.83
Perceived Efficiency	3.33	4.33
	4.33	5.00
	5.00	5.00
	4.00	4.67
	3.67	3.83
	3.67	4.17
Mean	4.00	4.63

Table N2.

Pre-/post-test survey results for perceived laboratory workspace of the surveying laboratory

Subscale	Pre 5S	Post 5S
Perceived laboratory workspace	2.67	5.00
	4.33	5.00
	3.33	4.33
	4.00	5.00
	2.33	4.33
	3.00	5.00
	5.00	5.00
	3.67	5.00
	3.00	4.00
	3.67	5.00
Mean	3.50	4.77

Table N3.

Pre-/post-test survey results for perceived equipment search time of the surveying laboratory

Subscale	Pre 5S	Post 5S
	3.00	5.00
	4.00	5.00
	4.50	5.00
	4.00	5.00
Perceived equipment search time	4.00	5.00
	3.50	5.00
	5.00	5.00
	4.00	5.00
	4.00	3.50
	4.00	4.00
Mean	4.00	4.75

Table N4.

Pre-/post-test survey results for perceived work environment of the surveying laboratory

Subscale	Pre 5S	Post 5S
Perceived work environment	2.50	5.00
	3.88	4.50
	3.13	5.00
	3.75	4.75
	3.38	4.38
	4.00	4.75
	5.00	5.00
	3.63	4.75
	2.88	4.00
	3.50	4.38
Mean	3.57	4.65

Table N5.

Pre-/post-test survey results for perceived safety of the surveying laboratory

Subscale	Pre 5S	Post 5S
Perceived safety	3.14	5.00
	4.29	4.43
	3.57	4.86
	3.71	4.71
	4.00	4.71
	4.14	5.00
	5.00	5.00
	3.71	4.57
	3.43	3.86
	3.57	4.14
Mean	3.87	4.63

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