PROCESS IMPROVEMENT THROUGH ESTABLISHED STANDARD WORK

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Abstract

In recent years, a line has been drawn that separates standard work from standardized work. Often considered foundational, standardization is about achieving consistency, or employing work measurement for flow optimization or task simplification. However, organizations that standardize may never realize the full potential of *lean*, which is process or system improvement. Standard work, in contrast, uses measurement to drive action. The contemporary view relies on visuals to distinguish normal from abnormal conditions, and to trigger problem resolution, or kaizen. While research overwhelmingly supports the learning of structured problem solving through a system, little is written on teaching the information flow in an educational or training setting. In this paper, a framework for connecting the flow of information for process improvement is demonstrated through simulation. In this study, current and past studies that contribute to the contemporary view of standard work were analyzed. Qualitative evaluation supports the use of simulation for teaching standard work in education, and the author suggests areas where further research is necessary.

Introduction and Background

Day [1] reiterates Taiichi Ohno's words, "…where there is no standard, there can be no kaizen". In early quality literature, standards commonly meant quotas, conformance, regulation or numerical measures that were acceptable or not acceptable [2]. Today, standards normally refer to an attribute, measurement, tolerance, target or requirement [3]. Continuous improvement relies on measuring against standards; so, if there are no standards, then there is no way to measure effectiveness or improvement.

Standards are achieved through standardization. The term 'standardize' is frequently associated with maintaining the first three S's—Sort, Set-in-order and Shine—in the 5S process [4-6]. Standardization commonly represents achieving a level of consistency or predictability by preventing variation in work tasks [7-9]. In many companies, standardized work is synonymous with SOP (standard operating procedures) [6], or the safest, easiest and most effective way currently known to perform an operation [10]. Standardized work is most often related to classical industrial engineering methods used for simplifying a product [8] or designing work activities. Time and resource measurements may be utilized to optimize production. Eliminating unnecessary steps, rearranging of operations, leveling, reviewing task sequence, matching production to demand, controlling work-in-process and putting into place mechanisms ensure stability in normal practice [10-12]. In systems, standardizing methods can prevent problems from reoccurring [13] and support adherence until a new improvement is made [14]. Shook [15] best described the dynamic role of standardized work and how this paves the path for continuous improvement by writing, "With standardized work, best practice is assured and the current best practice becomes the baseline for further improvement, or kaizen".

Standardization: Good for Change?

Without question, best practices should be captured and standardized; the absolute goal is kaizen, to identify muda, or waste, and continually develop processes. However, companies can regress if their standardized work fails to change [10]. A longitudinal study conducted on 119 organizations revealed that standardization can actually be problematic for change [9]. Huber et al. [9] note:

> Because standards are valued, and because organizational changes might lead to destandardization, change will more often be resisted in more standardized organizations. Consequently, it seems likely that organizational changes are less frequent in organizations characterized by greater standardization." (p. 239)

The analysis of findings in this study concluded that standardizing can lead to organizational efficiency, but can impede all types of change. Discussion with a CI manager at a Midwest company also supported this view. Often the problems encountered in production are lost after a temporary fix is applied. The manager's point is simple: Flow optimization or implementing measures that ensure that output matches what is planned, does not automatically help the process or system grow. High standardization, by itself, does not initiate the regular engagement in process improvement, or kaizen. The system must be designed so that when problems do surface, they are immediately captured, thoroughly documented, scheduled, solved and measured.

Standard versus Standardized Work

It is no surprise that standard work is underappreciated. Standard work and standardized work are often used interchangeably. While there is an abundant amount of literature on standards, standardization and standardized work, there is a clear absence of any universal *standard* definition for standard work. A brief search will reveal that the term standardized is often considered a poor translation from the Japanese meaning, and many do not distinguish standardized from standard. Mann [16], however, is one of the first to make a clear distinction, explaining that standard work is about management action taken to improve processes, and standardized work represents time elements for work including Takt, inventory amounts at stations and procedures. Duggan [17] contrasts standardized work and standard work by writing:

> Much has been written on establishing flow, standardized work and the visual factory. However, to grow the business, management needs to be freed from day-to-day operations. That happens by setting standard work for normal flow, making abnormal flow visual and creating standard work for abnormal flow so employees, not managers, can fix it. Management, then, can work on activities that will grow the business. (p. 29)

"Fix problems before they occur" is an integral result of developing and implementing standard work [16], [17].

Perhaps one of the more important contributions to standard work was captured in Costantino's [18] writing about the wood-processing company, Cedar Works. Standardized work methods such as work simplification, reducing non-value-added steps, balancing and developing work procedures were employed. Visual tracking charts that illustrated the performance of production with demand were essential in helping worker motivation, reinforcing change and identifying skill gaps. But it was through responding to undesirable conditions (wait times and line-stop conditions) that the latest model of standard work began to evolve. Since wait time resulted in variation, decision procedures were developed for line workers to restock areas, clean, assist neighbors and perform required maintenance. To reduce line stoppages, decision procedures were established to quickly deploy team leaders in the problem-resolution process in an effort to keep operations running. Developing If-Then actions eliminated downtime and eventually helped the company achieve a state of predictability and reliability.

Huntzinger [19] explained that problem solving is part of standard work and wrote, "Steady progress with continuous improvement depends on effectively incorporating improvements into Standard Work. Although 'ask why five times,' the informal version, subdues many problems, Plan-Do-Check-Act (PDCA, the Deming Circle) remains Toyota's fundamental problem-solving framework". In an LEI Lean Management Case Study, Plumbers Supply underwent a lean business transformation that involved developing standard work [20]. In the study, standard work was not just about developing procedures or checklists, but putting into place visual cues that indicate the presence of and subsequent action to rectify abnormal conditions.

Many lean practitioners differentiate standard work by implementing an improvement component or action. This is a noticeable separation between standard and standardized. Standardized work is almost universally associated with best practice, where improvements can still be made, while standard work is associated with seeing that the process is running as planned, problems are solved and processes are improved. Contemporary descriptions of standard work absorb and put into place kaizen activities, particularly closer to where work occurs. Although a review of the literature uncovered some differences in definitions and interpretation, closer examination did reveal shared themes in standards, standardized and standard work. Table 1 contains a simplified but collective comparison of standards, standardized work and standard work.

Standard Work for Kaizen

Stacks and Ulmer [7] explained that becoming a lean organization is about learning through root-cause problem solving. Many of the ideas of process improvement and preventing problems from reoccurring can be found in Deming's [2] writings. Deming described in simple language the Shewhart Plan-Do-Check-Act Cycle and how managers must take the lead to accomplish transformation. Scientific method models like PDCA and DMAIC are integral to continuous improvement. Schutta [21] adds, "Kaizen approaches involve using process thinking rather than functional thinking…The improvement process of kaizen uses Deming's plan-do-check-act approach to problem solving". PDCA is the structure for an improvement cycle that changes both standards and standardization [22].

Standard work is more than just job-instruction methodology or calculations. Standard work is about process or system improvement [10], [16], something that requires both awareness and understanding. Awareness is accomplished by identifying problems through visual control or detection of abnormal signals or misses. Andon or signal boards are effective in displaying to everyone, when and where a problem is occurring [7]. Pitch boards or tracking charts are

Table 1. Comparison of Standards, Standardized Work and Standard Work

	STANDARDS	STANDARDIZED WORK	STANDARD WORK
Sophistication level	Low	Intermediate	High
Meaning	● Target – Basis-desired condition	● Perform as planned - Expected ● Baseline for improvement	● Proactive -Taking action ● Analysis & Improvement
Function	● Support standardization ● Conformance ● Define normal (target)	● Enable/Support improvement ● Control - Simplify - Stabilize - Make routine and repeatable ● Become an efficient organization ● To achieve normal & recognize abnormal (departure from target)	● Process improvement action ● Development ● Become a learning organization ● Recognize & Act on abnormal
Primary Consideration	Desired performance	Current performance	Future performance
Question	What is the target?	Is the target reached? How can the target be reached?	Why wasn't the target reached? What went wrong? What is the remedy?
Elements	● Measurements ● Tolerances ● Regulations / Rules ● Ingredients ● Characteristics	● Work sequence or process steps ● Takt time calculation ● Inventory amounts (stock, SWIP) ● Layout planning	● Operator/Manager Action ● If-Then scenarios - Decision analysis - Contingencies ● Problem solving, Countermeasures ● Process/System adjustment
Format or Tools	Specifications Memos/Notes Illustrations Manuals Drawings Numerical	Standard operating procedures Operator instructions Balance or leveling charts Standard work process sheets Andon/Pitch boards, tracking charts Checklists/Audits	Pitch boards, tracking charts Decision diagrams Problem-Resolution Form Root-cause-analysis PDCA/DMAIC cycle Accomplishments board
Benefits	● Eliminate variation ● Consistency of output	● Eliminate variation ● Efficient work ● Stable operations ● Flow optimization ● Consistency of output	● Preventive - Eliminate variation ● Efficient decision making ● Change standardized work ● Stability - Prevent flow breakdowns ● Improve process/system

good for showing actual performance compared to expected performance. Awareness is also demonstrated through action to resolve the problem. Developing, selecting and implementing countermeasures are the PLAN and DO phases of the Deming cycle. However, implementing solutions to problems does not necessarily indicate that learning has taken place. Problems still can be solved using stop-gap techniques or temporary solutions that do not change standardized work. Such solutions do not result in process improvement, only a certainty that the organization is likely to encounter the problem again. PDCA involves system discipline, so learning takes place and mistakes are not repeated [15]. Understanding, or becoming a "learned" organization, requires follow-up to determine if the countermeasure was successful and subsequently taking some kind of action. If the countermeasure was successful, this should yield changes to either standards, standardized work or both. If the countermeasure was not successful, then the team should be sure the problem is correctly identified and, if so, then select an alternative countermeasure. Allen and Thomerson [23] reinforced the importance of change as problems are solved and wrote, "…the real aim of this process is for the operators to gain ownership of the standard work. Lean enables operators and gives them the skills to analyze abnormalities (e.g., quality issues, equipment downtime and overtime) and solve problems using plan-do-check-act/ adjust methods and statistical process control tools".

Standard work is the structure put in place to engage in kaizen, which is accomplished through the final two phases of the Deming cycle: CHECK and ACT. When processes or systems positively change, kaizen may result in changes to standards or standardized work. Figure 1 depicts Standard Work (leadership action) for problem resolution and process improvement using the Deming cycle. Leader standard work recognizes that standardized work will change as standards change.

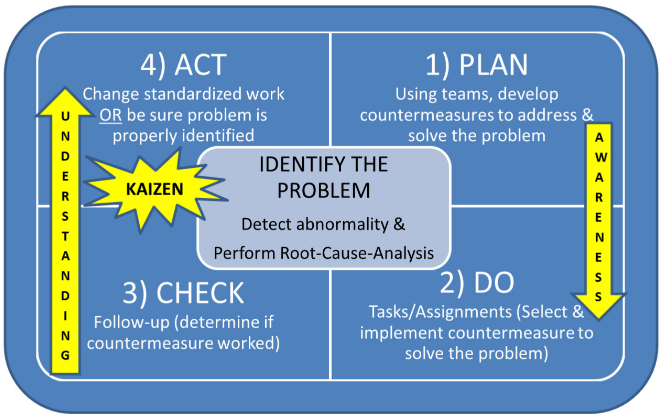


Figure 1. Deming Cycle for Problem Resolution & Process Improvement

Improvements should be connected to business performance; and having a mechanism in place to capture problems is critical. Strategy deployment is often conducted using a catchball approach that employs PDCA at operational, tactical and strategic levels [24]. Catchball refers to information sharing through the levels so that everyone understands the goals of the organization and becomes involved in problem solving for improvement. The decentralized method involves using team-based problem solving closer to where work occurs, promoting both horizontal and vertical integration. Measurements are recorded and dashboards are used to indicate performance metrics so that leadership can make informed decisions.

The power of standard work is found when the process or system changes and fundamental to standard work is the establishment of visuals to drive management decisions. Visual control is commonly described as making it possible for everyone to see whether the situation is right or wrong, or normal or abnormal [11]. Lean systems rely on visual indicators or signals that reflect standards to generate action. Dennis [10] describes three characteristics of standards and how they support visual management: "A standard is a clear image of a desired condition. Standards make abnormalities immediately obvious so that corrective action can be taken. A good standard is simple, clear, and visual".

Lean Simulation

For years, simulations have been used in training and education for replicating workplace practices and teaching lean flow techniques. The learning benefits and power of using simulations, particularly the mechanics of lean, have been well-documented. Participants get hands-on exposure and observation of process improvement [25-27]. Simulations can be very effective for illustrating visual control, understanding value streams, realizing the importance of reducing defects and learning how charts track performance. One simulation model demonstrated a method for engaging students in an improvement cycle using Lego-constructed airplanes [27]. Simulations have often been used to test scenarios for error and throughput. In a clinical setting, simulation has been used to examine the impact of lean practices on resource utilization, distance traveled, wait time and patient flow [28].

Problem of Opportunity

While simulations have been essential to teaching fundamental lean flow concepts, the exercises do not teach the development of, in the contemporary sense, standard work. Mcleod [25] explained that signal systems employed to illustrate process status can be challenging and difficult to explain in educational environments. Without structure, there can be disconnect in tying a visual signal of an abnormality to employing action that improves the process. Linking process performance to action presents a problem of opportunity, particularly in simulation development.

Methodology

Simulation was selected as the vehicle for delivering standard work instruction to 24 students in a junior-level, Engineering Technology Cost Reduction class during the fall, 2012, semester. Six students had some form of workforce experience. College-leavers quickly find that lean is not only being applied in manufacturing, but also office, healthcare, finance, agriculture, construction and distribution. Because most simulation participants did not have prior work experience, a general discussion of potential problems (abnormalities) in both production and service industries was necessary. Countermeasures, or problem-solving measures, were also discussed. Table 2 contains a condensed list of some abnormalities and countermeasures that can take place in a variety of fields.

Visual control techniques and their purpose are usually new for most students, even for those who have work experience. As a primer, participants were given detailed instruction on visual control techniques as used in industry. More than 100 pictorial examples (see Figures 2 and 3) of visual control were used to familiarize students with the value of organization, status and signaling. Supermarkets, FIFO lanes and Red-Amber-Green (RAG) color coding (status indicators) were presented to reinforce the simulation experience. Figure 2 illustrates First-In-First-Out (FIFO) control and sequence of repair work to be completed for plastic injection molding operations. Clipboards serve as kanbans, and the first repairs to be made are outlined using red boxes for the two FIFO lanes. In Figure 3, Andon lights use red and green to indicate process status differentiating normal from abnormal conditions.

Table 2. Forms of Abnormalities and Countermeasures

ABNORMALITIES
• Failure/Non-conformance in information, material, product, people, machine, process, system (cosmetic, functional, procedural, policy, design) • Amount/Level (conditions, information, material, people, orders, knowledge) • Schedule (interruptions, time delay, sequence) • Omission (missing information, steps, data, knowledge, parts, tools, equipment, personnel) • Safety (injury producing, environmental) • Geographical (location, placement, or delivery error)
COUNTERMEASURES
• Good communication (visuals, pictures, clear instructions) • Decision Logic (if-then scenarios) • Flow strategies (layout, balancing, sequencing, combining, leveling) • Quality checks or audits • Design changes (product, process, system) • Education (training, cross-training) • System approaches (DMAIC, PDCA)

Familiarity of basic flow fundamentals was necessary. The class had completed simulations that involved standardizing using Takt calculations, leveling and combining operations. Instruction also involved Value Stream Management and pull signaling with kanbans. Up to this point, all scenarios illustrated the mechanical side of lean, not the systematic structure and information flow for making process improvements. Before engaging in simulation, students needed to understand the purpose of the exercise. The following eight questions were displayed on a white board:

1. What is normal? (the target/standard)
2. How is an abnormal condition recognized?
3. How are leaders informed about the abnormal condition?
4. How is the abnormal condition documented?
5. How is action for a resolution process triggered?
6. How is the abnormality resolved?
7. What prevents the abnormality from reoccurring?
8. How is performance of resolving abnormalities measured?

Figure 2. FIFO Lanes Used to Control Work Sequence

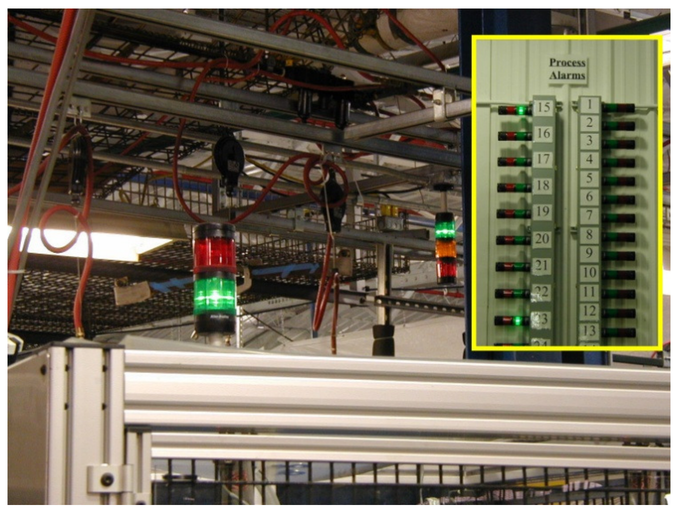


Figure 3. Andon Lights Used to Distinguish Normal from Abnormal in Processes

These questions were used to help students make the information connection necessary to show that lean is more than just about material flow; lean is also about flowing information to rapidly solve problems. The questions were to be addressed through standard work development and were revisited throughout the exercise.

The Simulation

It is important to note that the simulation chosen was not as important as the overall purpose for improving the process. A variety of simulations can be easily modified to incorporate standard work development. Due to time and spatial constraints of a university setting, the simulation chosen for teaching standard work was the assembly of a mechanical pencil.

Figure 4 depicts the initial architecture of the simulation, which involves four assembly operations and a final test operation. The exercise is activated by a pull signal from a finished-goods supermarket that contains three colors of the finished product. When an order of a particular color is made, a kanban signal is sent to Operation 3, where colored sleeves are assembled to the single Work-in-Process unit. The product is then transferred to a FIFO lane where the tips are assembled at Operation 4 and the product is tested at Operation 5 before being placed in the supermarket. The simulation uses pull for Operations 1 and 2, but in the form of visual control using designated spaces, thereby eliminating kanbans. WIP is held to one single subassembly unit between the first three operations.

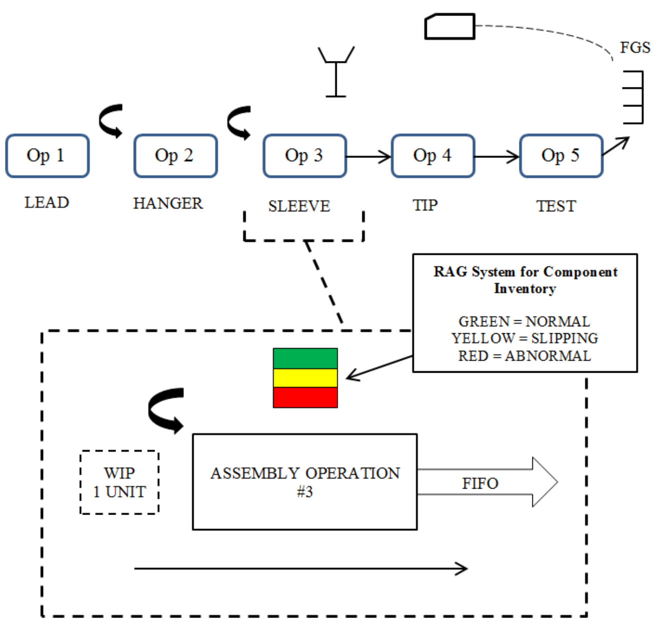


Figure 4. Simulation using Visual Control for WIP and Supply Chain Inventory

Several walk-throughs of the simulation were conducted to familiarize students with the mechanics of the assembly at the stations and flow of the material throughout the simulation. For instance, Operation 2 could not initiate assembly operations until the downstream customer, Operation 3, pulled the work-in-process unit. This simulation is comparable to many other single-piece flow simulations used in training, and provides a good starting point (current state) for making improvements. The mechanics of lean have been well-documented in the literature. Calculating Takt, balancing, changing sequence, combining and reacting to demand shifts are integral to future states of this simulation. However, these are omitted since the focus of this article is information flow and actions to resolve problems.

PLAN: Procedure Development for Normal and Abnormal

Each of the assembly and testing operations needed normal condition procedures. Students were divided into teams and assigned to a station. One team member was assigned as the team leader. Since participants had never had experience developing procedures, instructor guidance was given. Hernandez [29] outlines several points when developing systems and procedures:

1. Procedures should be concise.
2. Procedures should be meaningful to those who will use them.
3. Procedures should be dynamic and change with feedback.

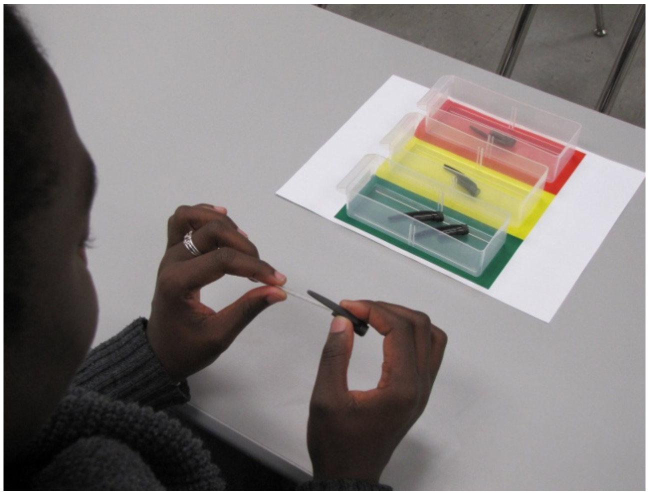
General procedures were reduced to 3-4 concise steps for each operation. Although essential in real-world applications, time limits made implementing visuals impossible.

The phase also involved developing operator standard work for the supply chain component inventory levels, or the parts to be added to the subassembly. Teams were encouraged to review the types of abnormalities provided in Table 2. To further guide students, the following guidelines were given:

1. Indicate the condition, situation or status.
2. Use IF-THEN thinking. Anticipate problems that can occur and what actions operators may take.
3. Make the operator-to-leader connection.
4. Generate a signal that drives leader action and follow-up.

Students were given the goal of developing procedures that drive action. Each assembly station was given a Red-Amber-Green sheet without documentation and a marker for writing. The sheet represented a buffer for in-process supplier inventory. Green color-coding represented normal component inventory, yellow represented slipping and red represented a critically low inventory level. Figure 5 shows the second assembly operation with color-coding for supply inventory.

Figure 5. Assembly Operation 2 with RAG System for Supply Inventory



A comprehensive approach was taken to show the application of all RAG conditions and how they can play a role in action. It is important to note that yellow conditions may or may not be necessary; many industrial applications simply have two conditions, green for normal and red for abnormal. Figure 6 illustrates a recreated example of student-generated standard work for component inventory at Operation 2, and actions to be taken if an abnormal condition becomes present. When an operator picks inventory from the yellow zone, the supply of parts necessary for assembly gets low, so the operator has to stop and record the event before resuming assembly. Recording the yellow condition gives the team leader a chance to respond and address the issue before reaching critical status. If the condition worsens, where the operator draws from the red zone, inventory becomes critically low and standard work tells the operator to halt assembly, record the problem and immediately notify the team leader. Similar procedures were developed at other stations.

QUANTITY = 3 UNITS	INVENTORY GOOD → 1) ASSEMBLE AS PLANNED
QUANTITY = 1 UNIT	INVENTORY GETTING LOW → 1) STOP & RECORD SLIPPING 2) FILL OUT PROBLEM FORM 3) RESUME ASSEMBLING
QUANTITY = 1 UNIT	INVENTORY CRITICALLY LOW → 1) STOP ASSEMBLING 2) NOTIFY TL IMMEDIATELY

Figure 6. Student-Developed Operator Standard Work for Normal and Abnormal Conditions in Supply Inventory

IMPLEMENT: Test Normal

Once the first phase of standard work was drafted, one member of each team was tasked with performing the operation. Procedures developed by the groups were shared with the entire class before testing. One team leader was selected and assigned to ensure that the five stations were running normally, or at least as planned, in the simulation. So, for the purpose of demonstration, six participants were engaged in the simulation, while the remainder of the class watched. Flow was initiated by the customer pulling from the finished-goods supermarket at the end of the five-process simulation. Initially, the simulation ran smoothly. Station restocking was based on a trigger signal from shipping; this was an important system characteristic because it did not allow for stations to cover up quality issues that might otherwise be hidden by a local pull signal. Green-zone inventory for assembly stations was replenished for every three products shipped from the finished-goods supermarket.

CHECK: Recognizing Abnormal

For students to engage in an improvement action, an abnormality must occur. Participants should be able to react to problems involving quality, time and shortages. In practice, various disruptions are presented in order to determine the effectiveness of standardized operating procedures and standard work for actions at each station. For instance, simulation disruptions involve delays, demand shifts and quality issues. This exercise offered endless possibilities for testing the system. The following scenario demonstrates a supplier quality abnormality in an effort to test student-generated standard work for the component inventory.

After several successful rounds, new inventory was replenished for each assembly station (as necessary). In the next cycle, a product was shipped from the finished goods supermarket, which sent a kanban signal to Operation 3. Operation 3 pulled the WIP subassembly from Operation 2, as expected. However, Operation 2 discovered a damaged component in the normal (green) zone in the attempt to assemble and replenish the WIP for Operation 3. Because non-conforming parts cannot be assembled properly, Operation 2 pulled again from the supply component inventory. Normal component inventory eventually became exhausted, and the operator began to tap into the yellow-zone inventory during the third activation (1 cycle prior to replenishment). Students immediately visualized the presence of an abnormal condition at Operation 2. Obviously, this was going to have a ripple effect downstream to Operation 3 for the next product shipped from the finished-goods supermarket. There was the threat that Operation 2 could not complete conforming work-in-process inventory ready for Operation

3. This situation quickly sensitized students of the importance of supply chain stability, and it was at this point that the effectiveness of local operator standard work was tested.

An essential part of this standard work phase was documenting the abnormal condition, no matter how small or large. It was through data collection that trends or patterns presented themselves. Now that an abnormality had occurred, a visual had to be registered so that the team leader would notice and a remedy, either short-term, long-term or both, could be applied. Since Operator 2 had tapped into the yellow zone (low inventory), standard work required that the assembly halt and the problem be recorded. To record the problem, a tracking chart was used. Charts can use numerical values or RAG color coding within a time interval or track expected versus actual performance in scheduled production (as in a Pitch or Andon board). Figure 7 illustrates a simple magnetic tracking chart that indicates normal or abnormal for a work time interval.

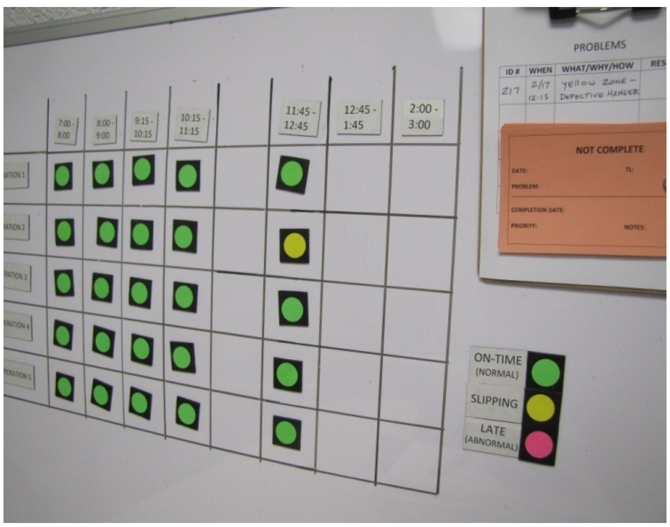


Figure 7. Tracking Chart for Normal and Abnormal

After recording the yellow or slipping condition in the appropriate time interval, the operator filled out necessary information on the Problem Form, as stipulated by standard work. Attached to each Problem Form was a red kanban to be filled out and used for task accountability and tracking. Operator 2 then returned and resumed assembly, as prescribed in local standard work. In this test, student-generated operator standard work was successful. If the problem was not resolved in a timely fashion, the following pull signal from the finished-goods supermarket to Operation 3 would result in a red dot, or imminent shutdown, because there was no WIP from Operation 2.

ACT: Leadership Action

In another scenario, a problem was captured and documented by the visual tracking chart and a Problem Form. The visual tracking chart can be used in conjunction with an accountability board. A task accountability board helps schedule problem solving, whereby leaders are responsible for follow-up resolutions to the problems discovered by operators. Documentation can be directly applied or transferred from the Problem Description Form to cards or kanbans, which are placed on the accountability task board. This allows everyone to see the status of improvements.

Figure 8 illustrates a task-board format for leadership action. This is easily color coded, where green represents "problem solved" and red indicates "resolution still needed." Boards do not require much structure. In the simulation, a chart was made using a whiteboard with 3"x5" index cards. Index cards are green on one side and pink on the other and can be easily taped to the whiteboard. Other formats involve green-pink sticky notes, magnetic flip cards or just using red and green markers. The kanban format allows for project prioritization to more easily take place. Task-board information can vary. In this simulation, information on the abnormality was kept to a minimum, indicating the date/time of occurrence, team leader and description of the problem. Expected completion date and priority would be filled out by the team leader. In this way, management can verify the status of solving the problem.

DAILY KAIZEN (PROBLEM & RESOLUTION)				
TEAM LEADER	2/14	2/15	2/16	2/17
John (area 1)				
Margret (area 2)				
Sally (area 3)				
Brad (area 4)				

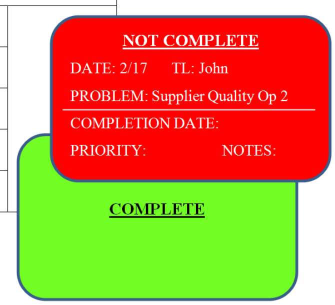


Figure 8. Task Board Format for Leadership Action

It is at this point that leader standard work is reviewed. Follow-up of an abnormal condition requires leadership action. Leader standard work may occur at timed intervals or at random. The visual tracking board makes it easy for the team leader to perform a quick scan in order to determine how the system is doing. Because the possibility exists that the leader is working on solving another problem, frequent, scheduled checking of the tracking board is helpful in preventing a shut-down situation. Standard work must define the how frequent the board is to be reviewed, and if-then scenarios should guide the action to be taken. Mann [16] explains:

> …leaders must quickly perceive the series of step-by-step actions to attack a flow interrupter or develop an improvement. This skill, the ability to see an implicit work-breakdown structure, is necessary to make appropriate one-step-at-a-time task assignments that cumulatively respond to the interruption or opportunity. Follow-up on these task assignments is straightforward with the visual daily task board on which assignments are posted. (p.77)

In the simulation, the tracking board displayed and documented a supply chain disruption for Operation 2. Table 3 showed leader standard work developed as a class. Following standard work, the team leader immediately recognized the yellow condition, retrieved the Problem Form with kanban and met with Operator 2. Once the facts were determined, new parts were delivered to Operation 2 and the kanban was placed on the accountability task board to look into identifying and solving the problem.

Table 3. Leader Standard Work

1)	CHECK TRACKING CHART EVERY 15 MINUTES.
2)	IF ABNOMALITY PRESENT, MEET WITH OPERATOR TO ASSESS SITUATION.
3)	DOCUMENT ABNORMAL CONDITION USING PROBLEM FORM.
4)	IS PROBLEM CRITICAL? YES → CONTACT MANAGEMENT NO → PROCEED TO STEP #5
5)	CAN PROBLEM BE FIXED IMMEDIATELY? YES → FIX PROBLEM & SUBMIT PROBLEM FORM TO MANAGEMENT NO → FILL OUT KANBAN AND PLACE ON TASK BOARD
6)	COMPLETE TASK BOARD ASSIGNMENTS

It is at this point that students made a connection between the abnormal signal and the problem-solving action through leader standard work. Similar to developing operator standard work, students had to account for how leaders were to follow through with action. Figure 9 illustrates leader standard work for the task board developed by using a logic diagram.

Students were again placed in their respective groups and the team leaders were charged with following leader standard work and addressing the kanban on the task board. It was through the PDCA process that changes to standards and/or standardized work would be made. For this simulation, the root cause was determined to be a non-conformance delivery by the supplier.

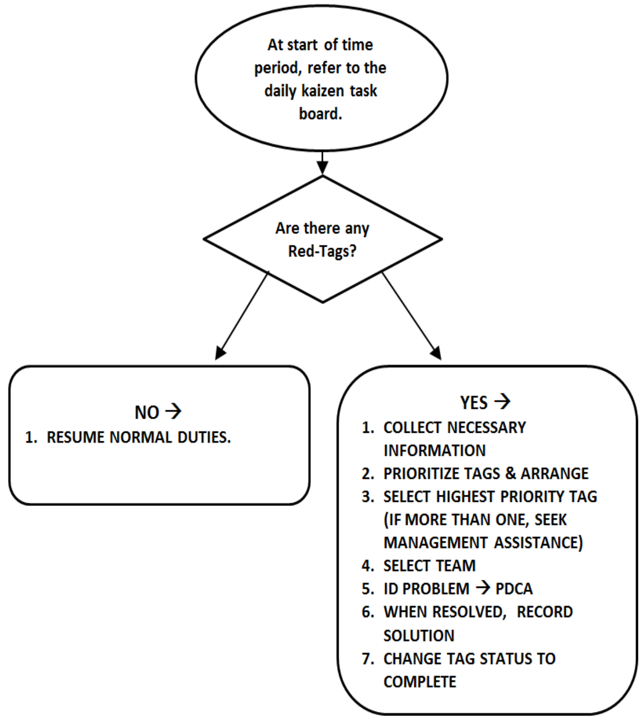


Figure 9. Leader Standard Work to Initiate Problem Resolution

Student teams were charged with resolving the problem and results varied as expected. Standardized work should not only make clear what is to be done, but also what is not to be done. Students were quick to realize that while they had developed assembly procedures for each operation, they failed to initially develop standard work to resolve problems. All students felt this was an indicator of a system shortcoming. In the example detailed, Operator 2 pulled from the yellow-zone inventory. A defective product itself is a visual indicator, and some believed this should not be tolerated. Accepting poor quality was not a good standard and should automatically be considered a red-tag condition, rather than waiting for inventory levels to trigger operator action. The class agreed that quality disruptions required immediate attention, since these could compromise the ability to satisfy internal and external customers. This logic changed the standard and resulted in a standardized countermeasure: If a defective part is encountered, then halt assembly and notify the team leader. Other suggestions indicated that component inventory amounts may need adjusting until the reliability of the supplier is improved. One team suggested having a quality check before delivery to the operation, or requiring the supplier to perform an inspection. Some responses involved seeking a new supplier altogether. All of these adjustments to the system or process were appropriate. Review of handling and design would also have been appropriate.

When a problem is resolved through PDCA, then a red-status visual on the task board can be changed to green. The Problem Form is updated to indicate countermeasure implementation and can then be sent to management. From here, a metric board can be used to analyze problem solving even further.

Evaluation

Generally speaking, students enjoy educational experiences when they are engaged in activities, especially simulations. Qualitative feedback from simulation participants included:

"Keep using the simulations - makes the class go by fast."
"Lectures are good, but the simulations are better for showing how things work."
"I can't wait to see this practiced in my job."
"My company applies kaizen without any direction. Now I understand how visuals and good instructions can lead to change."
"Information has flow."
"Lean is more than I first thought."

In this exercise, students collaboratively engaged in a closed-loop improvement cycle where visual mechanisms initiated front-line decisions. This simulation helped make the connection between an event that is visually captured and problem solving, demonstrating that lean tools are geared toward process improvement.

Conclusion

Standardization is about performance done right the first time, whereas standard work is about making adjustments to the process or system. The example just presented made system adjustments to an abnormality and standardized the improvement within the system in an effort to eliminate future supplier quality problems and to diminish rework. Where standardized work is commonly characterized by procedures to ensure uniformity or industrial engineering techniques for flow stability, a contemporary meaning of standard work incorporates visuals to drive the process improvement cycle. This movement or shift may be in part because more fields have adopted lean which, too, has fueled new ideas for advancement and growth.

There is still much opportunity for further study. For instance, analysis on standard work versus standardized work can be completed through industrial surveys or interviews. Researching the various techniques for teaching standard work (in a problem-resolution sense) is also very reasonable. It stands to reason that if standard work is one of the highest leverage tools in lean, then this should be taught in university programs. While much has been written on the importance of teaching the mechanical side of simulations, little has been demonstrated on how to implement information flow for process improvement in an educational or training environment. The writings of McManus et al. [27] suggest that many research opportunities exist in designing simulations to address this need. While the simplified example presented in this paper illustrates standard work for a supply chain disturbance, the same practices can be used for finished-goods inventories, cross training employees, monitoring flow of in-process work using Pitch boards or Heijunka boxes, completing business information requests and numerous other areas in a system.

Some organizations measure to the standard, while others use measurement to drive process change. Visual thresholds supported with decision logic can expose system weaknesses. It seems logical that all companies will benefit by having a blend of standardized work—that optimizes flow—and standard work—which uses a structured approach—for action to improve processes when abnormalities arise. Without this integration, follow-up may suffer and many if not most employees will be exempt from regular improvement of processes. Through study and application, it becomes evident that both standardized work and standard work evolve with system maturity. However, no matter what level of sophistication, recognizing, developing, implementing, testing and acting remain critical factors for the continued advancement of any system.

References

[1] Day, J. C. (1998). Learning about lean systems at Freudenberg-NOK: Where continuous improvement is a way of life. In Liker, J. K. (Ed.), *Becoming lean: Inside stories of U.S. manufacturers* (pp. 178-198). New York: Productivity Press.

[2] Deming, W. E. *Out of the crisis.* Cambridge, Massachusetts: MIT Press.

[3] Schroeder, R. G. (2008). *Operations management: Contemporary concepts and cases.* New York: McGraw-Hill Irwin.

[4] Feld, W. M. (2001). *Lean manufacturing: Tools, techniques, and how to use them.* New York: CRC Press.

[5] *Standard work for the shop floor.* (2002). New York: Productivity Press.

[6] Summers, D. (2011). *Lean six sigma: Process improvement tools and techniques.* Upper Saddle River, New Jersey: Prentice Hall.

[7] Stacks, C. & Ulmer, J. M. (2009). Applied lean thinking: general usage principles. *The Technology Interface Journal, 9* (2).

[8] Martin, J. W. (2009). *Lean six sigma for the office.* Boca Raton, FL: CRC Press.

[9] Huber, G. P., Sutcliffe, K. M., Miller, C. C., & Glick, W. H. (1993). Understanding and predicting organizational change. In Huber, G. P. & Glick, W. H. (Eds.), *Organizational change and redesign: Ideas and insights for improving performance* (pp. 215-265). New York: Oxford University Press.

[10] Dennis, P. (2002). *Lean production simplified: a plain language guide to the world's most powerful production system.* New York: Productivity Press.

[11] Hirano, H. & Black, J. T. (1988). *JIT factory revolution: A pictorial guide to factory design of the future.* Cambridge, Massachusetts: Productivity Press.

[12] Kosaka, G., Kishida, M., Silva, A. H., & Guerra, E. (n.d.). *Implementing standardized work at ThyssenKrupp in Brazil.* Retrieved January 11, 2013, from http://www.lean.org/admin/km/documents/6d8be412-c448-425d-b852-86962a16f736-SW_TK_English.pdf

[13] Harry, M. and Schroeder, R., (2000), *Six sigma: The breakthrough management strategy revolutionizing the world's top corporations.* New York: Doubleday.

[14] *Pull production for the shop floor.* (2002). New York: Productivity Press.

[15] Shook, J. Y. (1998). Bringing the Toyota production system to the United States: A personal perspective. In Liker, J. K. (Ed.), *Becoming lean: Inside stories of U.S. manufacturers* (pp. 40-69). New York: Productivity Press.

[16] Mann, D. (2005). *Creating a lean culture: Tools to sustain lean conversions.* New York: Productivity Press.

[17] Duggan, K. (2012). Flowing toward business growth. *Industrial Management, 54*(5), 28-30.

[18] Costantino, B. (1998). Cedar works: Making the transition to lean. In Liker, J. K. (Ed.), *Becoming lean: Inside stories of U.S. manufacturers* (pp. 302-387). New York: Productivity Press.

[19] Huntzinger, J. (2006). Why standard work is not standard: Training Within Industry provides an answer. *Target, 22*(4), 7-13.

[20] Drickhamer, D. (2009). *Lean in distribution: Go to where the action is!* Retrieved January 3, 2013, from http://www.lean.org/common/display/?o=2179.

[21] Schutta, J. T. (2006). *Business performance through lean six sigma: Linking the knowledge worker, the twelve pillars, and Baldrige.* Milwaukee, WI: Quality Press.

[22] Harrington, H. J. & Lomax, K. C. (2000). *Performance improvement methods: Fighting the war on waste.* New York: MaGraw-Hill.

[23] Allen, J. & Thomerson, G. (2008). Better way in vogue: Lean takes to the catwalk in the garment industry. *Industrial Engineer, 40*(11), 45-50.

[24] Bell, S. & Orzen, M. A. (2011). *Lean IT: Enabling and sustaining your lean transformation.* New York: CRC Press.

[25] Mcleod, A. (2009). Conceptual development of an introductory lean manufacturing course for freshmen and sophomore level students in industrial technology. *The Technology Interface Journal, 10*(4).

[26] Stier, K. (2003). Teaching lean manufacturing concepts through project-based learning and simulation. *Journal of Industrial Technology, 19*(4), 2-6.

[27] McManus, H. L., Rebentisch, E., Murman, E. M., & Stanke, A. (2007). Teaching lean thinking principles through hands-on simulations. *Proceedings of the 3rd International CDIO Conference.* MIT: Cambridge, Massachusetts.

[28] Farahmand, K., Karim, R., Srinivasan, R., Sajjadi, R., & Fisher, L. (2011). Lean Enterprise principles applied to healthcare. *International Journal of Engineering Research and Innovation, 3*(2).

[29] Hernandez, A. (1989). *Just-in-Time manufacturing: A practical approach.* Englewood Cliffs, New Jersey: Prentice Hall.

Biography

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