How problem-solving really works

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Abstract: Over the years, many researchers have proposed theoretical models of problem-solving. These models work a problem in a sequential and rational manner. Through our professional experience and an action research study, we discovered fundamental differences between what these models describe and what actually happens when problems are solved in a real-world setting. Assisting with a process improvement experience in a plastics company, we discovered that when a problem is properly identified, problem-solving generally follows the theoretical models. However, when a problem is difficult to identify, problem-solving proceeds in a cyclical and apparently irrational manner. Cyclical problem-solving increases the average time of problem-solving and production cost. The authors find that the relationships among the problem-solving steps are much more complex than implied in existing literature. Incorporating this new understanding into process improvement training reduced the variability of the problem-solving time from 44 to 21 min.

Keywords: problem-solving; process improvement; action research.
1 Introduction

The authors were recently asked to assist a plastics manufacturing company with process improvement efforts. The company’s goal was to decrease production costs by reducing time needed to solve process problems on the production floor. Our first step was to train employees on sequential problem-solving process. Over a period of several weeks, the authors provided over a 100 hour of training in the five-step (5S) problem solving technique. The technique begins with problem identification, information gathering, generating alternative solutions, evaluating solutions, and ends with implementing the best solution(s). In addition to training, the authors also participated in implementing 5S on the shop floor, as well as giving feedback to employees, observing progress, and documenting results in a research log.

The first 90 days following the implementation were extremely difficult. Line employees and supervisors struggled to apply an unfamiliar technique to a familiar manufacturing process. This required substantial discipline. While initial application of 5S was awkward, employees gradually gained proficiency in sequentially working
through each stage. However, sometimes the process seemed to break down, with employees failing to follow the 5S techniques in sequence. Instead, they attempted to solve problems in a cyclical, apparently irrational, and often adversarial manner. Although they eventually worked through problems, they did so out of sequence and with trepidation. This observation was not a surprise because during our combined 40 years of experience, the authors had seen it many times; but due to the small percentage of problems solved in this way, and constraints imposed by client companies the authors worked with, the authors did not investigate it further. In addition, evidence from existing literature suggests that problem solving sometimes occurs cyclical (Cougar, 1995). Cyclical means that participants may not be able to complete problem identification until the second step, after all information gathering and reviewing has taken place. Or, while generating alternative solutions, participants may recognise that there is a need for additional information gathering to complete problem identification step. However, no study addresses how or why it occurs, or the impact it has on process improvement efforts. More importantly, no study suggested how to improve a cyclical problem solving process.

Over time, it appeared that cyclical problem solving was occurring at a greater rate – with approximately 15% of all problems being resolved in this manner. After a few more months the ratio was well over 60%, and increasing. This was creating a problem because as the percentage of cyclical problems solving increased, so did the average problem solving time. The improvement in problem-solving time the authors experienced initially was deteriorating rapidly. Assuming the problem was due to a deterioration of the discipline needed to use 5S, the authors again participated in the process improvement effort to reinforce the techniques received during training. During this process the authors discovered that line employees had not actually abandoned the 5S technique. Instead, they were responding to situations when the technique did not work as expected. In other words, they were altering the process to fit the needs of the situation at hand. This gave us the impetus to investigate further.

In examining why 5S was not always working, the authors discovered an interesting trend – when the problem identification process went smoothly (i.e., the correct root problem was identified relatively fast – between 5 and 10 min) employees were able to identify and implement successful solutions sequentially. However, when the employees experienced difficulty in problem identification, (i.e., attempting to identify the correct root causes prior to developing alternative solutions and data gathering – as we had taught them), working sequentially through the 5S technique did not provide resolution. In fact, they often had no idea what created the problem. Eventually abandoning the 5S process after several hours of effort, employees would try many alternative solutions, chosen at random or through intuition. Then, investigating why the solution worked ultimately led to the correct root problem. Several employees described this experience as a struggle, often resulting in frustration and adversarial confrontation among workers and managers.

After almost a year, only 25% of the problem solving, occurring in the company, utilised the sequential problem solving. While some authors describe a similar ill-structured experience, there was no study suggesting how or why cyclical problem solving occurs. In addition, the authors found no study suggesting how to improve the problem solving process when it is conducted in a cyclical manner. This study suggests that cyclical problem solving is used to solve most problems in real-world settings.
Knowing how and why it happens is essential for reducing problem solving time, which means that process problems such as downtime and product quality will be resolved more quickly – resulting in reduced costs to the company.

The purpose of this study is to demonstrate how cyclical problem solving occurs in the real-world; to explain why it happens; and to suggest techniques for reducing problem solving time. The authors recommend that through the examples they provide, researchers develop a deeper understanding of problem solving approaches, \textit{i.e.}, how the relationships among their components are much more complex than implied in existing literature of problem solving.

2 The 5S problem solving technique and creativity

Successful process improvement implementation depends on the ability to identify and solve problems creatively (Kepner and Tregoe, 1965). Many authors believe problem solving and creativity as the same mental phenomenon (\textit{e.g.}, Guilford, 1964). Others consider problem solving as a form of creativity or creative thought (Mumford \textit{et al.}, 1994a–b). Creativity is also characterised as a special kind of problem solving that is the act of solving an ill-defined problem (Hayes, 1981). Creativity and problem solving are often combined into a single complex behaviour (Isaksen and Treffinger, 1985). When problem solving is characterised by original thinking, then by default, all problem solving is creative (Nickerson, 1999). These studies demonstrate that creativity and problem solving are inexorably linked and that the more difficult the problem, the greater the need for creativity. Over the years many authors have proposed conceptual models of problem solving which describe it as a step-wise process (\textit{e.g.}, Dewey, 1910; Wallas, 1926; Rossman, 1931; Polya, 1945; Johnson, 1955). In general, these models consist of a sequential process, involving four to six steps. The authors describe a sequential five-step (5S), step-wise technique used in providing initial training to the company’s production employees (Figure 1).

**Figure 1** Sequential model

![Sequential model](image-url)
3 Problem identification

Problem identification is accomplished through the creative thought process (Csikszentmihalyi and Getzels, 1971). It is the process of defining or discovering an idea or problem (Kay, 1994). The quality of the creative process can be improved by devoting time to discovering the root problem (Nickerson, 1999). This is because proper formulation of a problem can be more essential than its solution – which may be a matter of mathematical or experimental skill. Creative imagination is necessary in order to view a problem from new angles (Einstein and Infeld, 1938).

The authors propose that the phenomenon observed in their study can be partially explained by these theories. In short, the cyclical problem solving processes the authors observed were employees applying creativity to discover root causes that were not easy to identify. As these researchers point out, the creative process is often cyclical and reflective due to the complex and diverse ways in which human beings process information. Creative exercises often appear irrational to an observer.

4 Information gathering

Generally the next step in problem solving deals with information gathering. Gathering and analysing relevant information about a problem is a crucial first step in generating a creative solution. The information should be gathered beginning with an extended search and analysis of available information (Einstein and Infeld, 1938), from a variety of sources such as published material, interviews, observations, discussions, and impressions (Kepner and Tregoe, 1965). Information enables the organisation to study a problem from different perspectives (Isaksen and Treffinger, 1985). This allows discovery of facts, patterns, and relationships previously obscured.

These studies demonstrate the importance of accurate information in problem solving; however, current models show problem identification preceding information gathering. The authors found this sequence is not always followed in real world situations because some root causes are not easily identified and often require substantial information gathering preceding problem identification. This is especially true when the problems are complex or not previously identified – in other words, the problem is new to the process. In addition, the authors found that on a tactical level, manufacturing solutions typically involve keeping a production line running. In these cases, information gathering is done quickly, prior to problem identification, and that evaluating solutions and problem identification is often performed through brainstorming (Osborn, 1953).

5 Generating alternative solutions

For many models, the next step in problem solving is generating alternative solutions. This is often done through brainstorming. The objective of brainstorming is to generate a large quantity of new ideas and defer judgement (or criticism) until after the analysis. It is important to understand that the generation of ideas should be separate from evaluation of ideas; else the creative process is inhibited (Osborn, 1953). In other words, during the idea-generation step participants must keep an open mind and refrain from
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asking questions such as, “Why did you come up with that strange idea for a possible solution?” Instead, the question should be framed as “Could you elaborate on that idea?” (Kepner and Tregoe, 1965). Working with many diverse – and sometimes absurd ideas – is crucial to innovation because failure can expose important gaps in knowledge (Thomke, 2001). While some ideas will eventually be kept and others discarded, the point is to generate a large number of them. In the beginning, it does not matter if ideas overlap or contradict each other (Shingo, 1987).

These studies propose that the individual creativity necessary for generating alternative solutions is often squelched in the real world by rendering premature judgment on ideas. This problem occurs when line employees and supervisors emphasise the motivation behind a solution more than the logic on which it is formed. It is often found in companies with pejorative practices that emphasise criticism and disapproval. Instead, effort should be placed on encouraging creativity in individuals by avoiding premature criticism, generating as many plausible solutions as possible and then choosing the best solution – based on its likelihood of solving or improving the problem.

6 Evaluating solutions

The next stage in problem solving is evaluating solutions. One way to evaluate solutions is to design an experiment with ideas on a trial basis (i.e., in a laboratory or pilot production processes), obtain objective data, and study results (Deming, 1986). Experimentation not only serves to evaluate alternative solutions, but also demonstrates the benefits of various solutions to shop floor employees. By making the benefits visible, many people can be persuaded that improvements are really possible (Shingo, 1987). Thomas Edison often espoused that the measure of success is the number of experiments than can be packed in a 24h period (Hargadon and Sutton, 2001). While evaluating ideas it is important to keep in mind that the purpose is not to ‘kill’ ideas but to look closely and critically at them. The objective is not to find a single good idea, but to develop a pool of good ideas by evaluating, modifying, and improving them (Isaksen and Treffinger, 1985).

These authors emphasise that failed solutions actually improve understanding by exposing root causes and gaps in knowledge that were previously unrecognised. We find this to be particularly true when problems are poorly understood.

7 Implementing the best solution(s)

The last stage of problem solving is solution implementation. The most stupendous improvement plans will be ineffective unless translated into practice (Shingo, 1987). There has been little research on how to implement solutions because some researchers feel there is very little creativity involved in the process. However, others feel that the greatest need for creativity is in the implementation stage (Kepner and Tregoe, 1965). They suggest that the more radical the new idea (creative contribution), the greater the departure from the established habit and tradition, which increases the resistance to change. This increases the difficulty in gaining acceptance of a new idea. An appropriate plan needs to be in place to overcome people’s resistance to change because they are prone to the inertia of old ways of working. Frequently, extraordinary efforts are
necessary to lead people into new ways of working (Von Fange, 1959). Often at this stage, resistance of habit will prevent shop workers from implementing improvement plans. Indeed, such plans cannot be fully realised unless consent is obtained along with understanding, and unless tenacious efforts are sustained (Shingo, 1987).

This research emphasises the importance of not only identifying solutions that work at the moment, so that they can be implemented should the problem occur in another context, but that an ongoing process of discovering better solutions is essential.

8 The company

At the time of this study the plant was a member of the plastics division of Constar Inc. – a member of the Fortune 500 group. The plant is classified as a continuous extrusion facility located in the Southern US and was one of 20 plants owned by Constar. The plant employed 300 engineers, technicians, managers and line employees who processed Polyethylene (HDPE and LDPE), PVC, Polypropylene and Nylon resins. It utilised 20 production lines comprised of Bekum, Fisher, and other custom equipment. One characteristic of this industry is that technology has not progressed to a point of permanent resolution of all manufacturing process problems, i.e., not all problems can be resolved by experience or by looking up an answer in a technical manual. This makes the process somewhat dependent on intrinsic knowledge of its line employees.

The company is typical of a manufacturer specialising in extrusion processes that organise manufacturing lines around a single piece of processing equipment. Each line also contains anti-static treatment units and case erectors. A typical plant operates in both a ‘make-to-order’ and ‘make-to-stock’ environment. A typical line operator oversees three production lines. At the time of this implementation, the company was holding an estimated 5% of the domestic plastic container market (4 oz to 3 gal size).

9 Description of the implementation

Using an ‘action-research’ approach (Kemmis and McTaggart, 2000), the authors provided training in the 5S problem solving technique to supervisors and line employees. The authors used cases from several publications, writings, and videotapes to demonstrate the technique. Following the training, managers requested that the authors work with line employees until they adopted and properly used 5S. After two months, the line employees became proficient in the application of 5S. At this point the authors became observers, and would only intervene when asked. The benefit of action-research is that it allows direct involvement of researchers in improvement process. This is done so that insights into how improvements are made in real-world settings are gained. In other words, action-research helps compare practice to theory, thus revealing gaps in the literature. This level of detail is difficult to capture using statistical or case studies. Next, we discuss the key problems encountered during initial implementation.
10 Changing the culture

Several months prior to the start of training the authors conducted plant visits to evaluate process problems, identify education level of line employees, develop training material, gather base-line data, and design a protocol for conducting the study. The authors found it difficult to obtain honest responses and recommendations from the line employees in the presence of supervisors. The authors learned supervisors often used pejorative reinforcement with their line employees, even though it was not sanctioned by upper management. The reinforcement was manifested in the form of verbal intimidation following some infractions or mistakes by workers. The practice had created adversarial relationships between line employees and supervisors. Instead of reducing mistakes, the practice damaged workers confidence, destroyed cooperation between supervisors and line employees, and, in some situations, encouraged equipment sabotage. The authors had to tackle this issue in the beginning because effective problem solving is difficult to implement in an adversarial environment, Deming (1986). While the authors did not debate the effectiveness of such practices, the average time to solve a process problem was well above 1h. The authors requested supervisors to cease verbal abuse several months prior to our arrival, and attempt to develop a less adversarial environment and culture. Second, the authors learned that operators received no formal training on how to approach process problems when joining the company – limiting their training to ‘on-the-job’, and in the hands of other employees. Consequently, convincing long-time employees of necessity of formal training in reducing problem solving time was a challenge. After all, said one employee, “… we have been trained on other techniques, and they never work as touted, and the company usually stops using them after a few months…or when they do work, our individual workload is increased…” The authors also convinced managers that a lack of long-term commitment and proper training was increasing the average time to solve process problems – which complemented our request to formally provide training in problem solving. These actions were necessary in order to establish an environment where problem solving could be effective.

11 Sequential problem solving

Prior to the start of our study, problem solving on the shop floor was always conducted amorphously, with each line employee using their own form of a trial and error process. While more experienced employees developed their own systems, they rarely shared findings and solutions with less experienced workers, which often caused arguments and encouraged animosity. In addition, they rarely shared ideas on process solutions usually deferring difficult issues to an engineer. The problem with this approach is that engineers knew little about most ‘hands-on’ process issues, and usually recommended equipment or product changes that were impractical. Eventually, the line employees would find a way to resolve the problem, but at a cost to production time.

After two weeks of training, all line employees were asked to try 5S on their jobs. While 30% were immediately cooperative in the effort, 60% were skeptical and took a few weeks to begin using the system. The 60% were convinced to try the technique only after it showed early signs of success on the shop floor. In short, they saw how identifying the correct root cause of a problem, instead of a symptom, facilitated focus on
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long term solutions. This meant that process problems that used to occur frequently were now occurring less often – indicating that the solutions were working. There was less infighting among these groups and the result of sharing ideas and working through problems in a systematic manner was improving performance. After several weeks, line supervisors reported that the response time of the production department had decreased, indicating that problems were being resolved in much less time, and with fewer resources. The remaining 10% of workers, typically with most seniority, were pejorative about the effort complaining that the new technique was equivocal and too prescriptive. Over time they had developed their own problem solving process. While these employees espoused sharing of ideas, it took considerable effort to demonstrate how using their individual demarcated techniques actually inhibited problem solving. Ultimately, it took some form of managerial intervention to encourage participation, with three employees eventually finding other jobs. To reinforce cooperation, the company offered financial incentives to employees who cooperated.

Despite these setbacks, line employees gradually assumed ownership of the process. While they argued over which solutions were best to implement, the improvement in cooperation was unequivocal. Incidents of open conflict were declining leading to less animosity. It was clear that the 5S technique was positively impacting culture and performance of the production department. An important observation at this point is that line employees were initially trained to use 5S individually when identifying problems and generating suggestions. For example, line employees were trained to think of all possible practical solutions of a problem. Then, prioritise their solutions in the order which had the highest probability of solving the problem. Next, they were encouraged to talk to other line employees and supervisors to get feedback and propose an initial plan. Finally, if possible, they were to test their ideas on a single production line and adjust them if necessary. Table 1 gives a detailed example of how a real problem was solved using 5S.

Through observation and interviews with these line employees the authors first discovered why 5S was not always followed serially. In the next section, we provide examples and propose an alternative model to those in extant literature.

Table 1

<table>
<thead>
<tr>
<th>Problem identification</th>
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<tbody>
<tr>
<td>As an initial project, line employees chose to resolve a long-standing problem with downtime attributed to material shortages. Online reports, operators reported an average of 20–30 incidents of raw material shortages per month. Each time a line ran out of material, it usually meant at least 50 min of downtime. Since this problem was well-known, it required little creativity to discover.</td>
</tr>
<tr>
<td>Information gathering</td>
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<td>To determine if the problem was isolated or plant-wide, the employees spent several weeks reviewing previous twelve months of reports. In doing so, they found that each line ran out of raw material 20–30 times per month, on average. Therefore, they investigated further and found that the lines were manually fed raw material by each operator. If an operator was repairing another line, or was distracted in any fashion, the line would run out of material. Since this happened only once or twice per day, it went relatively unnoticed by management. However, when looking at a full month, the cumulative total downtime was significant.</td>
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</table>
Generating alternative solutions

After brainstorming for several weeks employees suggested solutions that either involved increasing manpower, or employing some form of technology. As the company did not want to increase the number of workers, a project team decided to investigate a technological solution. In doing so, many of the members visited other plants to see how they resolved the issue. Most facilities that addressed the problem employed a combination of manpower and technology to resolve, with mixed results; however, in one facility the entire material delivery process was automated. While this required an initial capital investment of approximately $100,000, the savings in lost production paid-back the initial investment in 18 months.

Evaluating solutions

Since the plant that currently utilised the automated system used slightly different raw material, the group needed to test it under real conditions. To do so, the shop fabricated a small system capable of handling one line at a cost of approximately $5,000. The operators were told not to supply any material to this line by hand, rather wait until they run out of material before intervening.

The team reviewed the operator reports daily for the two lines under test. After 30 days, the lines had run out of material three times. Therefore, the team estimated that effective capacity of each line could be increased by 10–15 h per month (20–30 downtime incidents * ½ h each).

Implementing the best solution(s)

The new material system was purchased and installed over a 60-day period; however, the system utilised a pumping mechanism of 10 lbs. of pressure per line smaller than the one in the other facility. The group knew that the system could be made more reliable by using a higher-pressure pump, however, since the smaller pump worked in the field trial, it was chosen. During the implementation, operators were trained on the use of the system.

While the machine operators liked the system, the material handlers did not. Currently, three handlers were required to keep the old system operating. Under the new system only one handler was required, effectively eliminating two jobs. Plans were made to re-train the material handlers to perform other duties. However, they were not capable, and in the end they did not adjust to the new system and were terminated.

To verify that the new system was working, the team tracked the implementation. To their surprise, the number of material shortages increased. Further investigation revealed that the pumping mechanism was too small to do the job. Therefore, the technicians replaced the 10 lb. unit with an 18 lb. unit.

12 It is not working as touted – cyclical problem solving

The authors found many instances when 5S was not followed sequentially as indicated in existing models. When the root cause of the problem was not properly identified, none of the alternative solutions worked. This occurred frequently when problems were complex and poorly understood. In these cases, the problem was only accurately identified after a solution was developed through trial and error, or through more data gathering. Then, investigation of why the solution worked eventually led to the root cause. In these cases, the problem solving process occurred as generating alternative solutions, evaluating solutions- randomly until one worked, information gathering, and then problem identification. In Table 2, the authors provide a detailed example of a problem which was solved cyclically and reflectively. While this example presents a clear picture of cyclical problem solving, it was conducted over a two-month period, which is unusual for most process problems.
Table 2  Problem solved in a cyclical and reflective manner

After the new unit was installed, few material shortages were noted on the operator’s reports; however, downtime due to routine maintenance had increased by 5%. The line employees searched for a reason behind the increase in maintenance time, but according to discussions with operators, they were not taking more time than usual. In this example, maintenance downtime is not listed as a problem because it is a symptom, not a root cause. In order for problem solving to work, root causes must be identified.

Generating alternative solutions

Line employees were experiencing frustration with this problem. Since they could not identify a root cause, alternative solutions were solicited through brainstorming. Arguments ensued over suggestions such as more training on how to perform maintenance (which operators felt was unnecessary), better tools (which engineers felt was unnecessary), steps to reduce absenteeism (which could not be logically tied to the problem), and more security in the plant (which would reduce what some employees thought was sabotage).

Evaluating solutions

The team conducted an experiment to discover whether or not actual maintenance had increased. They obtained standard time to perform maintenance from manufacturers and compared it with before and after procedures the line employees followed. They discovered that operator’s actual maintenance time had not increased. However, at this point the employees did not see how any of the alternative suggestions could work.

Information gathering

The line employees decided to gather all data on maintenance records over the previous 12 months to verify maintenance time. A group of employees formed a project team to review records, and verified that maintenance time had not changed. However, one team member discovered that the downtime problem occurred in the same month as the implementation of the material handling system. In addition, he noticed that when the material system was down for two weeks, the old system was temporarily reinstated. During this two week period, downtime due to maintenance had dropped.

Problem identification

The team devoted one full day to brainstorm ideas. At the end of the day, there was consensus that operators had been performing maintenance during times when the production line was down for other reasons – such as material shortages. This meant that the downtime was reported as material shortage, not maintenance, and actual maintenance time was understated and hidden. When suggested to operators, they confirmed this fact, although they admitted they had never connected the two issues.

Generating alternative solutions

Three alternative solutions were identified. Better operator training to reduce maintenance time. Do maintenance on shifts when the production lines are not operating. Redesign lines to require less maintenance.

Evaluating solutions

The problem root cause discovery was that there was no immediate solution. The production lines were no longer down for material shortages, and had to be shut down specifically for maintenance. Since the plant operated 24/7, there was no other time to perform maintenance. Since it was determined that the operators had sufficient training, the only alternative solution was to redesign the production lines to need less preventative maintenance – and the technology did not exist to do so.

Implementing the best solution(s)

Since the technology to redesign the line did not exist at the time, the problem was turned over to engineering. After 30 days nothing had been done, because engineers had other priorities and did not want to tackle a difficult problem. Managers however were determined that a solution be found, because it was costing the company’s productivity. During three months of brainstorming ideas, the engineering department decided to redesign the line so that some preventative maintenance could be done while the machine was operating. They relocated lubrication points to the exterior of the equipment, and installed dual cutting mechanisms so that one could be stationary and maintained while the other was operational. This meant that the line could be partially maintained while still operating.
To outside observers, this process appeared irrational. To participants, it was frustrating. Workers rejuvenated the phrase, ‘It is not working as touted – again’. When this occurred, there was argument over which solutions to try first. Once employees realised that none of the solutions worked, they argued whether the solutions were incomplete or the problem was misidentified. The arguments wasted a number of resources and often required managerial intervention. Others blamed the failure on the problem solving training the authors provided saying that it did not work as expected. These events also caused frustration on the part of managers, some wanting to abandon the process. They also caused the researchers to question the wisdom of implementing 5S technique.

13 Additional training

It is evident from our experience that when 5S did not always work sequentially, it created a great deal of confusion, anger, animosity, and blame among line employees. Therefore, the authors held a third round of training sessions for line employees. The distinguishing differences between the initial training provided and the new training content can be summarised in five points:

1. The authors explained how problem solving does not always occur according to 5S. By this time, line employees were extremely skeptical of the value of 5S, and had to be encouraged to attend the sessions. However, once the authors presented several examples and showed that they understood the issue, the participants became more interested. The authors then taught the 5S process in a cyclical manner using the data in Table 2.

2. The authors advised line employees, when confronted with a process problem that will take more than 10 min to identify, to immediately solicit suggestions from other line employees. If they cannot identify the problem, gather more information. For example, examining prior shift reports to see if the problem has occurred previously and how it was resolved. If this does not help, use your intuition and, where safe and possible, try alternative solutions until one works. This will give you clues into the root cause. (Ten minutes was initially chosen as a starting point because most process problems in the plant were either identified in less than 10 min, or more than 40.)

3. The authors demonstrated how difficulty in problem identification may effect emotions and induce anxiety or anger – especially when working under strict time pressures. The authors also encouraged them to avoid blaming other employees and managers. It is OK to acknowledge you are angry, but try to relax and remain calm. Unless requested, do not skip designated breaks. This exacerbates anxiety and anger.

4. The authors recommended line employees to be patient and obtain engineering assistance if the problem has not been solved within 30 min. Patience and understanding is extremely important when working with complex problems, and that working through the process will eventually yield solutions. (30 min was arbitrarily chosen by managers as a starting point.)
The authors explained that just because the 5S steps are not always executed in the same sequence, does not mean the process is not systematic. Follow guidelines for working within each step as practiced in training and presented cyclical problem solving model (Figure 2).

Figure 2  Cyclical model

14 Discussion

5S problem solving begins with problem identification, information gathering, generating alternative solutions, evaluating solutions, and ends with implementing the best solution(s). In our implementation experience, the authors found that when problems were easy and they were clearly identified, problem solving proceeded in a sequential and rational manner. However, when problem were difficult and they were not clearly identified, problem solving proceeded in a cyclical and reflective manner. Cyclical means that participants may not be able to complete problem identification until the second step, after all information gathering and reviewing has taken place. While generating alternative solutions, participants may recognise that there is a need for additional information gathering to complete problem identification step.

The authors find that cyclical model is important for organisation learning or knowledge creation. According to Lee (2005) and Meyer and Sugiyama (2007) there are two types of knowledge. Explicit knowledge is openly expressed and knowledge can be documented or stored as information source. By contrast, tacit knowledge is not openly expressed and knowledge cannot be documented or stored as they are drawn from individual’s experience, insights, and intuition. In order for an organisation to continuously learn, tacit knowledge has to be converted to explicit knowledge. The
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proposed cyclical model for problem solving along with additional training could be applied to convert tacit knowledge into explicit knowledge to enhance organisational learning and provide impetus to process improvement effort.

Cyclical model of learning and improving system design is well supported in the existing literature with slightly different steps than our 5S problem solving. For example, Falconer (2006) showed a cyclical model for learning (converting tacit to explicit knowledge) that cycle through getting information, reflecting and processing, interpreting and engaging, and acting. In describing organisational learning and Six Sigma implementation, Savolainen and Haikonen (2007) explained Six Sigma methodology involving DMAIC cycle of define, measure, analyse, improve and control. McFarland (2008) described a spiral model for improving systems design:

- determine objectives, alternatives, constraints
- identify and resolve risks
- develop the deliverables for iteration and verify they are correct
- plan the next iteration.

Similarly, in order to improve new product design Chakravorty and Franza (2009) utilised DMADV cycle define, measure, analyse, design and verify.

In addition, the authors believe that appropriate organisational conditions are necessary to support the cyclical model and induce learning. Lustri et al. (2007, p.189) described three such conditions as:

1. **Environments and relationships**: “a solicitude environment…adequate level of informality; interactive relationships; and openness to knowledge sharing (social environment)”

2. **Structures**: “…without departmental barriers, with a communication infrastructure that will support and facilitate the flow of information and ideas (communication and collaboration components)”

3. **Managerial policies and actions**: “promoting information dissemination; sharing future visions, goals and strategies… group learning conditions and situations that foster knowledge creation and sharing.”

The authors know that, while a little or no description has been provided, many of these organisational conditions directly or indirectly facilitated our implementation. Future research needs to include these conditions to revise our proposed cyclical model to develop a comprehensive model for problem solving which promotes organisational learning and process excellence.

15 Conclusions

This research discovers a gap between theory and practice of problem solving within the process improvement domain. First, when the problem was clearly identified, problem solving generally proceeded in a sequential and rational manner as described in existing literature. Based on their research the authors conclude that, without exception,
corporate training programmes should teach these methods to managers and other employees. However, the authors found that many real world problems cannot be solved in this manner.

The authors conclude that cyclical problem solving occurs when problem identification is complex and difficult to formulate before other steps. The authors suggest how problem solving time and process costs can be reduced by training employees on how to work with cyclical problem solving. Using revised training content the average time to solve a process problem decreased from 47 to 35 min. However, the greatest improvement occurred in problem solving variability. The standard deviation to solve problems dropped from 44 to 21 min. While the authors were not permitted to present actual cost data, managers estimated that production costs were reduced by approximately 3%.

When there is insufficient information or understanding to identify the root cause, problem solving generally proceeded in a cyclical and reflective manner. Since employees were not initially trained on how to deal with cyclical problem solving, they became frustrated and angry. This inhibited cooperation, which led to increased problem solving time at a cost to production. Therefore, the authors propose that in addition to traditional training, employees should also receive training on problem solving sequences that do not follow the prescriptive path. Most importantly, to realise that frustration and anger are normal, but remaining calm is essential. Line employees and managers need to understand that reflective behaviour is important for solving difficult problems and, at times, may appear as irrational behaviour.

Lastly, the authors find that companies engaged in implementing change programmes such as electronic commerce, technology transfer, cell formation, and Six Sigma, also encounter similar problems. In many cases, these programmes are abandoned because of numerous problems, resulting in wasted resources and lost competitive position. One area of future research is to determine how much of this difficulty is due to characteristics of change programmes and how much is due to the inherent nature of problem solving.

References
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