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Quality Process Improvement Tools and Techniques

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1. Improvement as a problem-solving process

We see process improvement fundamentally as a way of solving problems. If there is not an apparent or latent problem, process improvement is not needed. If there is a problem, however intangible, one or more processes needs to be improved to deal with the problem.

Iterating between thought and practice.

Once you sense a problem, good problem solving technique involves alternating between the levels of thought and experience,[1] as shown in Figure 1. For instance, after you sense a problem, you should collect some data to get insight regarding the area of the problem, choose the specific relevant improvement activity you will undertake, collect some more data, analyze the data to find the causes of the problem, plan a solution and try it, collect some more data to evaluate the effects of the new solution, standardize on the solution if it works, and conclude by reflecting on what you did.

Unfortunately, people all too often use poor problem-solving practices, as shown in Figure 2. One poor approach that we are all familiar with is to stay only at the level of thought, as shown in row A of Figure 2:

a. sense a problem
b. dither — waste time on intermural squabbling
c. declare a solution — usually by someone in a position of authority
d. forget about it — nothing changes

In the approach of row A, no data is ever collected. No hypotheses are ever tested. A conclusion about the solution is jumped to without confirming what the problem and its root cause are. Naturally, the declared solution seldom works.

Another poor approach we are all familiar with is to stay only at the level of experience, as shown in row B of Figure 2:

a. people are working hard, typically fighting fires
b. some sort of new emergency arises, interrupting what is happening already
c. heroic efforts take place to deal with the new emergency
d. people go back to what they were doing before

In the approach of row B, no time is spent trying to draw conclusions that may improve things in the future; no hypotheses are ever drawn from the data.

[1] Our figure of the alternation between thought and experience is essentially the same figure as shown by Box (1978) on page 2 and Neave (1990) on page 141. In this and the following figures, the level of thought might range from well-founded hypotheses to unfounded guesses, while the level of experience might stand for anything from informal participation in a situation to structured collection of empirical data.

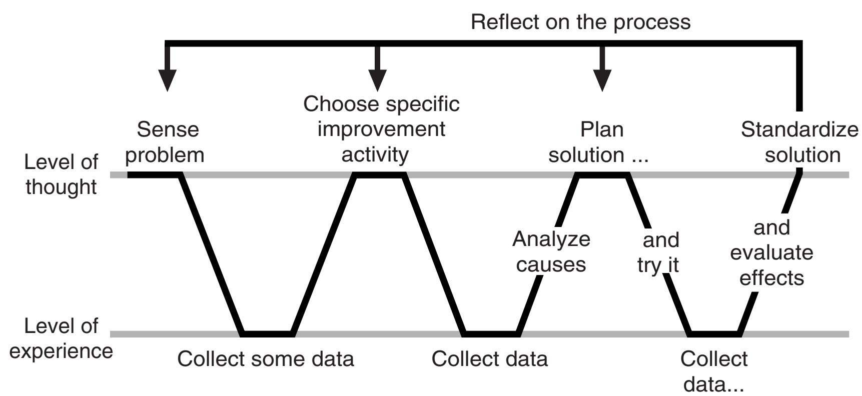

Figure 1. Alternating between theory and experience

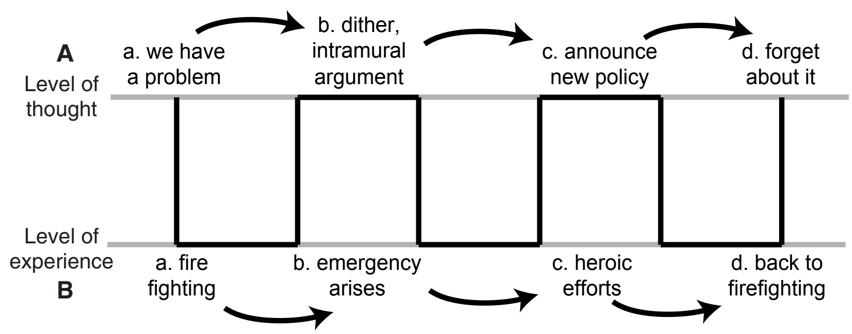

Figure 2. Not alternating between theory and practice

Thus, to make improvements that actually work and to improve efficiency over time, we must have alternation between thought and experience.

Three types of tools

When people talk about problem-solving tools, they often are referring only to analytical tools for understanding what a problem is and correcting it. However, the analytical tools are only the tip of the iceberg. To get tangible results, people need to be familiar three different types of tools, as shown in Figure 3. Before we can make use of analytical tools, we must have people who know how to use them; this suggests the need for tools for helping people acquire skill in use of the analytic tools. However, even when people have skill with the analytical tools, the odds are against them successfully attacking the right problem and actually solving it unless there is a good process for execution of the improvement project; this suggests the need for tools to execute projects.

Sections 2 through 4 of this chapter provide further discussion of these three different kinds of tools.

2. Tools for analysis

We'll start by discussing the analytic tools that traditionally are what people have in mind when they talk about process improvement tools (the tools at the left side of Figure 3).

The up-and-down transitions of Figure 1 are the basis of a model we call the WV Model, because the shape is roughly like a letter W followed by a letter V. In addition to emphasizing the importance of approaching problem solving by alternating between thought and experience as was discussed in Section 1, the WV Model also illustrates three different kinds of problem solving, as shown in Figure 4. There are different tools for different kinds of problem solving; it is important to decide what sort of problem you are attacking so you can apply the appropriate sort of tools.

Control. The problem may be to maintain a standard process and result for an existing process. This is shown by the letters SDCA in the control process portion of Figure 4: you have a **S**tandard process; you use or **D**o this process; you take data and **C**heck whether the process is still working as specified and still giving a specified result; finally, you **A**ct appropriately by either continuing this SDCA cycle or by embarking on an effort to make the process again work as planned or to change it to produce a newly desired result.[2] This is, of course, the domain of statistical process control as well as of other tools.

Reactive improvement. Alternatively, you may need to eliminate a problem with an existing process (for example, defects, mistakes, delays, waste, and injuries) in a way that

[2] The first three letters of what we are calling the SDCA cycle are closely related to Shewhart's "three steps in a dynamic scientific process of acquiring knowledge" (Shewhart 1939, pages 44-46): I. Specification (=standard), II. Production (=do), III. Inspection (=check). Although Shewhart didn't include the fourth letter (A) of SDCA, it was implicit in the way he drew his three steps as a cycle. Deming taught Shewhart's cycle as having the four steps (Deming 1982, page 88), which are commonly referred to as "Deming's PDCA cycle," standing for Plan-Do-Check-Act. The Act step stands for acting appropriately, e.g., *adopting* a process improvement that was planned, tried (=do), and checked, *abandoning* a proposed improved that didn't work out, or (frequently) running through the cycle *again* under changed conditions (Neave 1990, pages 139-149).

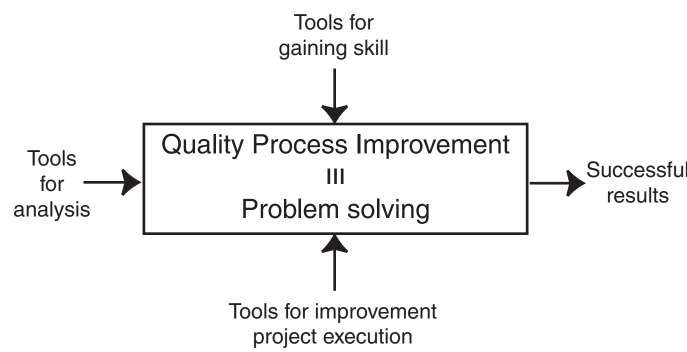

Figure 3. Three types of tools for successful process improvement

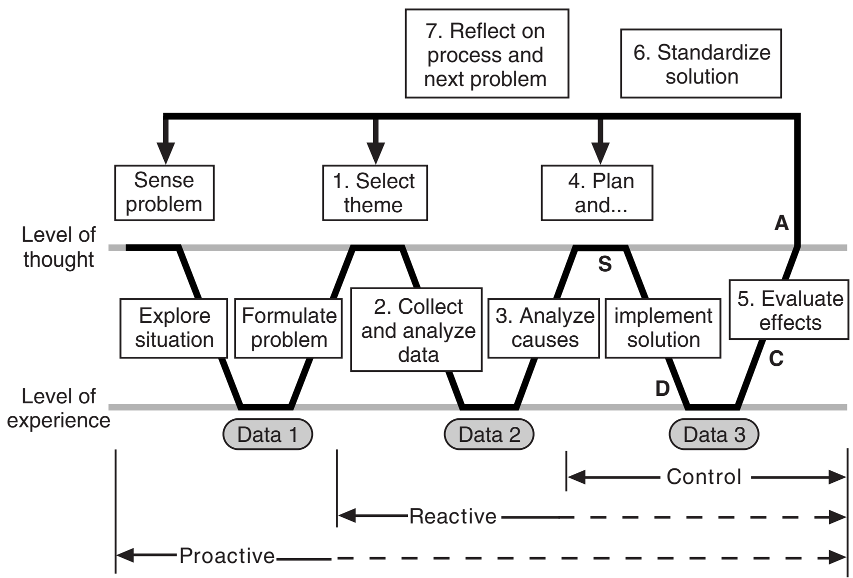

Figure 4. WV Model

prevents recurrence of the problem, or you may need to improve the specified result or capability of an existing process. Reactive improvement problems such as these can be effectively and efficiency attacked using a structured problem solving method process such as that sketched in Table 1 and in the numbered boxes in the right two thirds Figure 4. The process sketched in Table 1 and Figure 4 is commonly known as the 7 Steps of Reactive Improvement. There are other well-known structured processes for reactive improvement with various numbers of steps (typically 6 to 8). The exact method doesn't matter. What matters is that the method used involves alternation between thought and experience as shown in Figure 4 and deals with the sorts of issues listed in Table 1.

Table 1. A Reactive Improvement Process

1	State specific problem — think about what problem you should be trying to solve and clearly specify it
2	Collect data — collect appropriate data to confirm your assessment of the problem and investigate the source of the problem
3	Analyze causes — analyze the data, draw appropriate conclusions from it, and hypothesize the root cause(s) of the problem
4	Plan and implement solution — evaluate possible ways to eliminate the source of the problem and try the best
5	Evaluate effects — analyze the trial data to see if the problem in fact seems to be fixed; if not, it's time to return to step 1
6	Standardize solution — permanently modify the process
7	Reflect on the process — consider what you learned about problem solving that can improve your skill for the next problem

Proactive improvement. Your problem may be to replace an existing process or create an entirely new process to realize a new opportunity. This is indicated by the proactive improvement portion of Figure 4. However, the scope of a proactive situation is often larger and less structured than for control and reactive situations and, thus, may require more cycles between thought and experience as illustrated in Figure 5: *sense* a problem with the existing system, collect some data to help *investigate* in general what new solution is needed, *plan* how to collect a broad range of relevant external data from which new requirements may be determined, *visit* potential users on-site to collect the requirements data, analyze the requirements data and *deduce* key requirements, *test* the proposed requirements in the marketplace, *conceive* many possible (perhaps innovative) solutions to the validated requirements, select and integrate among the possible solutions to produce the best specific overall specification to *implement*.

<u>Different types of data</u>.

The WV Model of Figure 4 also illustrates that the three different types of problems typically have different types of data. Process control typically involves numeric or quantitative data (data 3 in Figure 4) for objective measurement of deviation; thus, the relevant tools are for analyzing numeric data. Proactive improvement typically involves qualitative or language data (data 1 in Figure 4) because definition of the problem is a bigger part of the task and the available data is typically words from external or internal

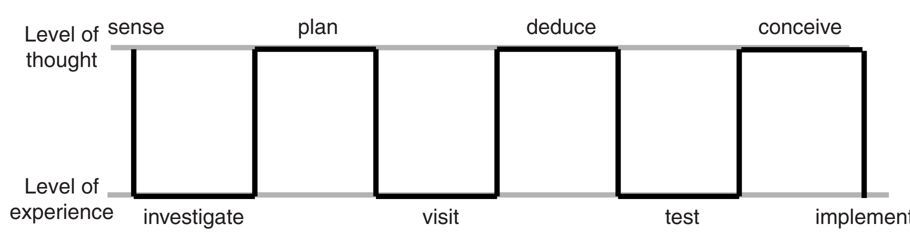

Figure 5. Example of alternating "WV" steps of proactive improvement

customers; thus, the relevant techniques are for analyzing qualitative or language data. Reactive improvement typically involves a mixture of quantitative and qualitative data (data 2 in Figure 4), thus, tools and techniques for analyzing both numeric and language data must be used.

Iteration

We have already described in the WV Model an alternation (iteration) between thought and experience within one problem-solving effort — in order to adjust theories based on real world data. However, the WV Model also involves iteration in the sense of repeating the problem solving effort:

- because more information may be available over time because of a changing situation and from new users
- to solve a tractable problem in a timely fashion (if too big a problem it attacked, it may never get solved, or by the time it is solved, the solution may no longer be relevant)

The principle of iteration is frequently stated in the form of Shewhart's or Deming's famous PDCA cycle — make a **P**lan, **D**o it, **C**heck the result, **A**ct appropriately, and cycle back for another iteration on the same problem or for the next problem.[2] The fundamental idea of iteration (PDCA) is learning. To eschew PDCA is not only arrogant; it is inefficient and often ineffective.

Specific analytic tools

In a single chapter, we must focus on issues of technique and some principles and models (as we have been describing in Section 2) to help a practitioner choose and successfully apply the tools. There is not space to describe specific methods. The appendix lists some common analytic tools and provides pointers to descriptions of them in the literature of quality improvement.

3. Tools for gaining skill

If you are to successfully use the analytic tools, those tools have to be taught to your people who have to gain skill with their use. Thus, tools are needed (as shown at the top of Figure 3) for developing skill. We see two major domains that must be addressed: how the analytic tools are structured, and how the analytic tools are taught.

Structure the analytic tools to be step-by-step

We strongly recommend use of explicit, step-by-step analytic tools and problem solving processes. An example is shown in Table 1 (where the seven elements listed are, as already mentioned, an improvement process known as the 7 Steps of Reactive Improvement). We recommend using an explicit, step-by-step process for several reasons:

- Making a method step-by-step creates a process that can be taught and improved (it's practically impossible to improve the intangible — mostly bad form becomes more ingrained).
- The resulting step-by-step method can be communicated across different people — for mutual learning, for benchmarking and comparison, and to attack large problems involving many people.
- Sometimes a method results that can be broadly applied (beyond the initial problem) — for instance, the 7 Steps shown in Table 1 have been used by every kind of person on myriad types of problems.

An important adjunct to an explicit, step-by-step process will be the use of standard forms and formats. Use of standard forms avoids time wasted debating the appropriate way of presenting each new bit of analysis, allows easy communication and collaboration throughout the organization, supports review and coaching to improve individuals' skills, and helps eliminate instances when important aspects of an analysis are accidentally skipped.

Inevitably someone objects to the teaching of explicit, step-by-step improvement methods. "They don't deal with real life complexity," he or she may say. However, people generally learn a new skill by starting with some rules of thumb (something like what we are calling explicit steps); and, through repetitive use, the learner discovers what each step is actually about and how to apply it more appropriately. Thus, repeatedly applying a step-by-step method and reflecting on what it means is a highly efficient way for a novice to begin to gain the necessary experience that can lead first to competence and then expertise with a method.

<u>Create an appropriate infrastructure for gaining skill with the analytic tools</u>

Some of the important aspects of a powerful infrastructure for developing skill with analytic tools are noted in the following paragraphs.

Create a learning system. The education system for the analytic tools should be treated like any other improvement problem — the problem of insufficient skill. Carefully plan and monitor inputs (curriculum, students, and teachers). Operationally define outputs. Alternate between thought and practice. Feed results back to improve the process.

Just-in-time training. In many cases, it is best not to separate analytic tool training from routine work. It is better to find ways to create opportunities for training as part of daily work. Experience with the problem before training makes the training seem more relevant. The ideal, often, is to deliver training in a sequence of little just-in-time doses, as part of solving a real problem.

Make use of line people. Often an improvement team has an improvement facilitator to help it. The characteristics of the improvement facilitator can be a key to success or failure. Using highly capable and respected line people in facilitation roles indicates management is serious about improvement and provides improvement teams with facilitators with useful organizational contacts and experience in making operational trade-offs.[3]

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[3] Of course, there are many training and improvement improvement specialists of great skill. However, all too often the position of improvement specialist is a dumping ground for people who are not highly valued

4. Tools for improvement project execution

Everyone has seen instances where good tools are well taught, but application of the tools doesn't result in real success. Sometimes the wrong problem is solved. Sometimes, the right problem it attacked, but its solution in blocked in one way or another. Thus, it is necessary to have a further set of tools for improvement project execution (as shown at the bottom of Figure 3).

As shown in the bottom part of Figure 6, a good solution to a problem requires the ability to sense the problem in the first place, to appropriately understand and frame the problem, and to find and implement a powerful solution to the problem and thus achieve the required result. However, successfully moving through these steps requires the capability to frame and solve the problem which means having people who are able to frame and solve the problem, as described in the following subsections.

<u>Capable improvement team</u>

As shown in the top part of Figure 6, there are three key components for having people capable of framing and solving a problem.[4]

Right people. It has become common wisdom these days that the people involved with the process having a problem should be involved in fixing it. These people are most familiar with the process and its parts and often have access to the best data. Furthermore, we want these people to feel they can make a difference so they will point out future problems that the organization can benefit from fixing. Almost as obvious to include are those who initially sense the problem and those who are needed to implement a solution to the problem.[5] Another group that should be involved are those who are affected by the problem and its solution, such as the next process, customers and suppliers. Finally, some organizations have found great benefit in including on the improvement team complete outsiders to the process, to bring fresh eyes to the improvement project. One company we know has had good success structuring their "Kaizen events" with one-third of the improvement team being directly from the process team, one-third of the improvement team being people affected by the process, and one-third of the improvement team being people who know nothing about the process[6] (LaBlanc 1999).

Good dynamics among people. The fundamental issue of good dynamics is building trusting relationships among the participants. Trusting relationships come from an iterative cycle involving clear discussion of possibilities to find shared concerns and

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for "more mainstream" operational roles. Such dumping must be avoided at all costs, or other members of the improvement team immediately will conclude that management is not serious about making improvements (and may not be in touch with operational reality). By rotating your best managers and individual contributors through the role of improvement facilitator for 12 to 18 months, the organization can develop over time many line people who also have the specific skills of process improvement, greatly aiding in a change of culture toward better process improvement. The improvement facilitator role is too valuable to waste on weak performers who are dumped into it.

[4] See also chapter 9 of this book on Teams and Teamwork. Ancona (1999) is also relevant.

[5] Of course, there may be overlap in the three groups just mentioned.

[6] And, in fact, may come from outside the company.

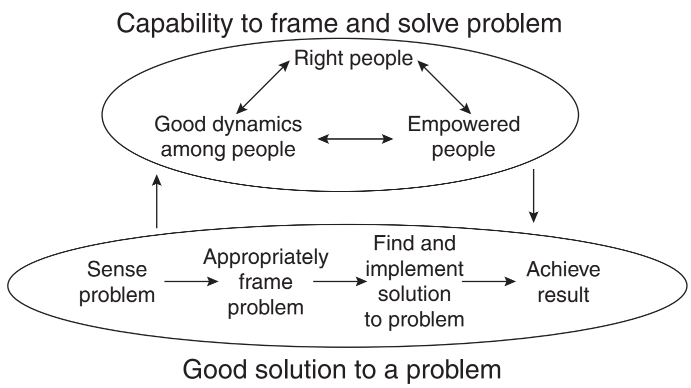

Figure 6. Capability for successful improvement project execution

successful execution of agreed upon actions, which in turn lead to more trusting relationships. (On the other hand, biased or manipulative discussions of possibilities and the resulting failures of action lead to mistrust.) Some important aspects for clearly discussing possibilities and finding shared concerns are balancing inquiry and advocacy, making reasoning and unconscious assumptions explicit, and processing qualitative data. Specific tools for these are discussed in the writings of Argyris, Flores, and others.[7]

Empowered people. Finally, the improvement team must be able to actually make changes — be "empowered," to use current jargon. However, it's not sufficient to just talk about empowerment. You must have a concrete idea what empowerment means to you, for instance, having the following components:

- engagement — having the motivation to spend the time and emotional and intellectual energy to do the problem solving
- authority — being required and allowed to do the job by those in positions of greater authority and allowed by those who can interfere with progress
- capability — having the capability to do the problem solving, e.g., trained to use the relevant tools (as discussed in section 3)

And your project execution tools must provide for these components of empowerment.

<u>Good solution to problem</u>

As shown at the bottom of Figure 6, a finding a good solution to a problem requires more than just sensing the problem and jumping to a conclusion. You must make sure you understand the situation broadly enough to be sure you are attacking the right problem. Then you must find a relatively powerful solution among perhaps many inadequate solutions. The fundamental rule is to avoid jumping to conclusions about what the problem is, what the solution is, and what the appropriate tool is.

Gather context and properly frame the problem. Before trying to solve a problem, you must investigate the situation to gather some context that can inform the choices that will be made. For instance:

- With a reactive improvement problem, don't begin immediately to work your way backward the chain of cause-and-effect. First, work your way forward through the chain of cause-and-effect to make sure solving the problem really matters (e.g., to customers or the financial well-being of the company); then, work backward to the root cause of the problem.
- For proactive improvement problems, it is especially important to talk to and observer a broad range of potential users regarding the capability to be developed. We recommend use of the five principles from Kawakita (Shiba 2001, pages 201-204): take an unbiased 360-degree look, maintain flexibility to seize unanticipated investigatory opportunities, increase your sensitivity to the problem by concentrating on it, listen to your intuition, and seek qualitative data (various case studies and personal experiences rather than large statistical samples).
- Regardless of the type of problem being addressed, the person or team doing the improvement needs to spend part of the improvement effort in the real world.

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[7] See, for example, Argyris (1985) and Flores (1993). See also Shiba (2001) pages 62-66, 217-221, and 297-328.

> Our name for such on-site observation is "swimming in the fish bowl," as shown in Figure 7. Rather than merely looking at what is going on in the real world (either with or without a prior hypothesis), instead first get involved in what is really happing (jump in the fishbowl and swim with the fishes) and then climb out and consider what you have heard and seen. Look particularly for what we call *symbolic images* — specific instances of behavior or specific events that are representative of a fundamental trend.[8]

Any such investigations may result in you changing your mind about what kind of problem you should address and may help you decide what tool to use or possible to change the tool you are using. In some (perhaps rare) cases, you may decide that there is an entire new business opportunity that you would do well to pursue.

Implement the improvement project. Ultimately, the improvement team must actually carry out the project (using some sort of project management process). Correct framing and analysis of the problem usually leads to an idea for a solution. Further analysis of available data refines the possibilities for solution. Next, a method for solution is chosen, and its implementation is planning and implemented. The project management process should conclude with a step of reflecting on the result (and deciding whether another improvement cycle is required) and on the process (to feedback possibilities for improvement to the improvement project); such reflections can also lead to improvement of all three types of tools shown in Figure 3.

There are a number of explicit processes (involving many different tools and subtools) for successfully implementing improvement projects. Two explicit process that we are familiar with are the Managing Teams approach (CQM, 1998) and the Four Gears Process (Ridlon, 2002).

The Four Gears Process is summarized in Table 2. Each stage and step of the process can be considered to be a tool, in addition to the detailed tools within steps such as creating a stakeholder role table. The Four Gears Process is oriented toward "managing without authority" and, thus, it is quite comprehensive; however, these methods will prove useful even when authority (supposedly) is in place. Stage 1 of the Four Gears Process gets the *right people* involved. Stage 2 and part of Stage 3 support *good people dynamics*. The rest of Stage 3 and Stage 4 involve actually *implementing a change*.[9]

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[8] For more about the fishbowl and about symbolic images, see (Shiba, 2001), pages 230-239 and 334-338.

[9] The Managing Teams approach (CQM, 1998) has more explicit methods for *empowering* improvement teams than the Four Gears Process does, given the latter's emphasis on working without authority.

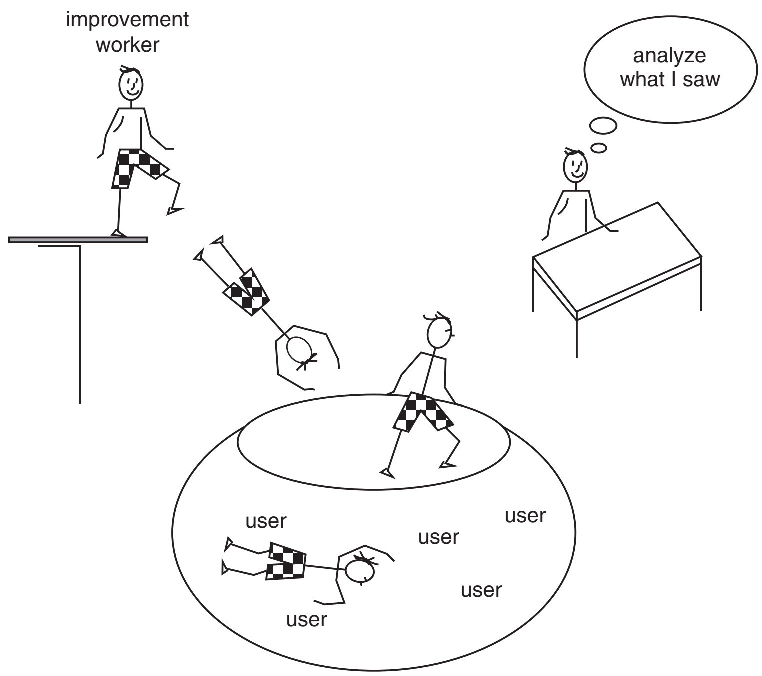

Figure 7. Swimming in the fish bowl

Table 2: Stages, steps, tools and methods of the Four Gears Process

Stage number and name	Stage objective	Steps	Tools and methods	The tools and methods are used to: ...
1. Initiate collaboration	Figure out who needs to be involved, how they need to be involved, and how to involve them	1. Map the network of individuals inside boundaries 2. Specify possible roles of those in the network 3. Identify key points of influence 4. Develop action plan for initiating collaboration	- Network map - Stakeholder role table - Influence map - Collaboration action plan	Identify the people who need to be part of the collaborative effort that is required to accomplish the tasks
2. Demonstrate integrity	Work to establish trust and understanding of shared concerns. Consider diverse perceptions through open discussion and debate	1. Assess and improve the level of trust in the relationship 2. Conduct a ground exchange of views 3. Articulate shared concerns	- Trust evaluation table - Cycle of reasoning - Advocacy and inquiry	Determine how to build trusting relationship with the people with whom you need to collaborate
3. Generate understanding	Frame the opportunity, develop a solution, and devised a plan of implementation	1. Agree on a topic 2. Write and understand the data 3. Group similar date 4. Title groups 5. Lay out groups and show relationships among groups 6. Vote on the most important low-level issues and draw conclusions	- Language Processing diagram	Gain consensus on how to frame the issues
4. Create commitment	Align the organization and assess commitment to action	1. Request (or offer) 2. Agreement 3. Completion 4. Assessment	- Commitment process	Initiate, coordinate and complete the actions required to deliver business results; provide organizational support for doing so
Conclusions and reflection				

5. Summary

We have described process improvement as a problem-solving process and listed three types of tools needed to accomplish the problem solving. The tools and techniques are a means of learning and communication:

- The analytical tools provide the path for communication between the problem and the problem solvers.
- The skill-gaining tools provide a learning process, supported by organizational infrastructure to gain greater benefit from the learning.
- The project execution tools provide a way to get tangible results, based on the learning and communication.

Problems exist as we see them. Until we can see a problem, it doesn't exist for us. After we see it, it exists as we initially see it. If we can see it better or differently, the problem changes and perhaps becomes solvable or otherwise goes away. The tools and techniques we have mentioned in this chapter provide the capacity to effectively and efficiently see problems.

Process improvement
A never ending cycle
Quality for life

Acknowledgements

Our thinking has drawn heavily our reading of many experts on process improvement, such as the authors of the books and papers listed in the bibliography. Specifically for this chapter: Dave Hallowell provided insight about the most commonly used statistical tools of Six Sigma; Bill DuMouchel provided a succinct definition for DOE.

Bibliography

Many of the books listed below are available either new or used (try an Internet search); some books will have to be sought in a library having a good selection of books on quality improvement. More pointers to descriptions of the tools and methods in other books will be found in the following books.

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Appendix. Brief List of Some Common Tools and Techniques

Descriptions of many frequently used tools and techniques not listed in this table may be found in references listed in the third column of the table. The text in the second column of the table has sometimes been copied or paraphrased from one of the references cited in the last column.

Tool name	**Summary statement**	**For more information** bibliography items (page numbers**)**
5 Ss	Methods of keeping a work area organized for maximum productivity.	Hirano
7 QC Steps (QC Story)	A set of steps to follow in solving many kinds of problems (also used to report on the improvement process).	Kume (191-206), Brassard 1994 (115-122), CQMc, Karatsu (11-13)
Affinity diagram	Organizes ideas and issues so as to understand the essence of a situation and possible follow-on actions.	Brassard 1989 (17-38), Brassard 1994 (12-18), Ozeki (246-250)
Analysis of variance	Comparing various estimates of variation among subgroups to detect differences between subgroup averages.	Wheeler 1990 (83-110)
Arrow diagram	Shows the network of tasks and milestones required to implement a project.	Ozeki (273-280)
Benchmarking	Comparing your process with a "best in class" process to learn *how* to improve your process.	Spendolini
Brainstorming	Allows a team to creatively generate ideas about a topic in a judgement-free atmosphere.	Brassard 1994 (19-22)
Capability measures and ratios	Various ratios and measures of the natural variation of process outputs (for instance, 3 standard deviation limits) and specification limits.	Brassard 1994 (132-136), Wheeler 1992 (117-150), Ozeki (195-203)
Causal loop diagram	A more sophisticated cousin of a relations diagram	Senge (87-190)
Cause-and-effect diagram (or Ishikawa or fishbone diagram)	Organizes data in terms of cause-and-effect such that the root cause of a situation may be revealed.	Brassard 1994 (23-30), Wadsworth (310-313), Kume (25-33), Ishikawa (18-29), Ozeki (150-158), Karatsu (62-83)
Central tendency and dispersion of data	Measures of the location and spread of data, e.g., mean and standard deviation, median and range, etc.	Wadsworth (74-80), Wheeler 1992 (22-26), Ozeki (185-194), Kume (143-156)
Check sheet (tally sheet)	Tallies (e.g., ||||) of problems or characteristics appropriately organized on a page.	Brassard 1994 (31-35), Wadsworth (292-300), Kume (91-134), Ishikawa (30-41), Ozeki (159-169), Karatsu (44-61)
Control chart	Quantifying variation and separating signal from noise. Typically used to monitor that a process is continuing to operate reliably; also used to detect if a change to a process has had a significant effect.	Brassard 1994 (36-51), Wadsworth (113-284), Wheeler 1992 (37-350), Ishikawa (61-85), Ozeki (205-235), Karatsu (131-157), Kume (92-141)
Design of experiments	Strategies for selecting a limited number of runs (observations of responses) in a possibly high-dimensional factor space so as to gain the maximum information about how the response values depend on the factors.	Box, Lochner
Flow chart	Graphical representation of the steps in a process or project.	Brassard 1994 (56-62), Wadsworth (320-324)
Graphs and graphical methods	Many different techniques for showing data visually and analyzing it.	Ishikawa (50-60), Ozeki (121-137), Karatsu (158-217), Wadsworth (325-351)
Histogram	Shows the centering, dispersion, and shape of the distribution of a collection of data.	Brassard 1994 (66-75), Wadsworth, (300-306), Wheeler 1992(27-30), Kume (37-66), Ishikawa (5-17), Ozeki (172-178), Karatsu (116-131)

Language Processing diagram	A more structured and effective version of an affinity diagram, derived from the same source as the affinity diagram (Jiro Kawakita's KJ diagram).	CQMa
Matrix data analysis	Various multivariate analysis methods.	Mazuno (197-215)
Matrix diagram	Shows multi-dimensional relationships.	Brassard 1989 (131-166), Brassard 1994 (85-90), Ozeki (265-272)
Pareto chart (analysis, diagram)	Like a histogram but with the data sorted in order of decreasing frequency of events and with other annotations to highlight the "Pareto effect" (e.g., the 20 percent of the situations that account for 80 percent of the results).	Brassard 1994 (95-104), Wadsworth (306-310), Kume (17-23), Ishikawa (42-49), Ozeki (139-147), Karatsu (24-43)
Poka-yoke (mistake proofing)	Methods to prevent mistakes from happening.	Shingo
Process decision program chart (PDPC)	Explicitly lists what can go wrong with a project plan (organized in a tree diagram) and provides appropriate counter-measures.	Brassard 1989 (167-196), Breasard 1994 (162)
Process discovery	For an activity, making explicit the customers, products and services, needed inputs, customer requirements and measures of satisfaction, process flow, and so forth.	Shiba (95-106)
Queuing theory	Analysis of delays and waiting lines.	Reinerston (42-67), Hall
Regression analysis	Analyzing the relationship between response (dependent) variables and influencing factors (independent variables).	Brassard 1989 (39-70)
Relations diagram	Shows a network of cause-and-effect relationships.	Ozeki (251-256), Karatsu (84-95), Brassard 1989 (197-229); see also Brassard 1994 (76-84)
Run chart or record	A version of a scatter (x-y) plot where data values over time (the x axis) are plotted (on the y axis).	Brassard 1994 (141-144), Wheeler 1992 (32), Wadsworth (313-320)
Scatter (or x-y) diagram (plot)	A graphical way of showing correlation between variables.	Brassard 1994 (145-149), Kume (67-86), Wadsworth (313-320), Ishikawa (86-95), Ozeki (237-243), Karatsu (106-115)
Sampling	Selecting a few instances from a set of events from which to infer characteristics of the entire set.	Ishikawa (108-137), Breyfogle 1999 (6, 294-335); see also indexes of Grant, Wadsworth, and Wheeler 1992
Statistical tests	For instance, various ways of testing hypotheses.	Kume (157-190), Breyfogle 1992, Breyfogle 1999 (6, 294-335)
Stratification of data	Classification of data from multiple viewpoints, such as what, where, when, and who.	Pande (chapter 14), Ozeki (179-183)
Tree diagram	Organizes a list of events or tasks into a hierarchy.	Brassard 1989 (97-130), Brassard 1994 (156-161), CQMb, Ozeki (257-263), Karatsu (96-105)