Building process
improvement capacity:
Structuring problem solving as
skill-building exercises

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ABSTRACT

Research that linked experience, improvement, and competition has shown that learning – both in the form of practice with existing processes and in the form of process improvement – can create performance differentials among competitors who are otherwise similar in product, production technology, market, and cumulative output. How does an organization develop its capacity for process improvement – specifically, how can one practice such a process or skill? One can’t simply repeat the same process improvement in order to get better at it.

Practice builds skills with existing products and processes, in part by bounding novelty and the introduction of complexity in order to maintain stability within learning cycles. Process improvement, by contrast, often requires increasing the number and range of experimental factors to search for the best product and process changes. This paper focuses on the means by which process improvement capacity is developed, and, indeed, how it can be practiced.

Building theory from exploratory case studies, this paper proposes that building process improvement capacity is an intermediating process that structures experiences of process improvement in order to maximize learning (rather than to maximize process improvement itself). It does so by bounding the process improvement experiences, for the short term, in the following ways. (1) Managers must coach and frame the context rather than offer technological solutions to those who are learning to solve problems. (2) Many experimental factors must be held constant so learners can try simple experiments in familiar situations rather than complex, multiple-factor trials. (3) Learners must be allowed to try experiments frequently in volume – perhaps more so than a parsimonious design for experiments might require. (4) Results must be observable with feedback from the process and its users.

KEYWORDS

Process improvement, problem solving, adaptive learning, learning curves, learning by doing

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1 INTRODUCTION

1.1 THE RESEARCH QUESTION

How is an organization’s process improvement capacity built? How is the ability to (1) determine a process’s weaknesses and (2) decide how to change the process for the better conveyed from one who has these skills to others: team members, employees, the organization?

Answers to this question are important both to academics in the operations research community and to managers and executives responsible for the current and continued success of their organizations.

1.2 CONTRIBUTIONS OF THIS RESEARCH

This question arises from the research community’s longstanding interest in the link between experience and performance improvement. For instance, the Rand Corporation (Asher, 1956) estimated learning curves – relationships between cumulative output and the unit cost of production – for airframes, and the Boston Consulting Group (1968) studied how learning curves affected competitive dynamics.

Other researchers have shown that practice and process improvement are the mechanisms by which experience leads to performance gains. Yet, these are not complements. They introduce novelty at different rates and achieve different outcomes. For instance, narrowing task-ranges in factories provided more cycles of process-specific experience, leading to labor productivity increases (Skinner, 1974). Bounding novelty introduction sped the rate at which surgical teams mastered a new procedure (Pisano, Bohmer, and Edmondson, 2001). In contrast, novelty and parameter variety facilitate experimentation for process improvement. For instance, using equipment in context advances process knowledge because problems that are encountered prompt the recognition and control of increasing numbers of variables (Jaikumar and Bohn, 1992; von Hippel and Tyre, 1995). Testing multiple factors at multiple levels leads to higher quality product and process designs (Taguchi, 1993). Practice and process improvement can actually
disrupt each other because they require different degrees of process stability (Adler and Clark, 1991). Thus, there are two learning modes, as in Figure 1, that differ by context and outcome.

Figure 1: Learning modes: Practice and process improvement

<table>
<thead>
<tr>
<th>Method</th>
<th>Context</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practice relationship</td>
<td>Stable process parameters</td>
<td>Master the process</td>
</tr>
<tr>
<td>Use the process as designed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Process improvement relationship | Varied process parameters | Change/improve the process |
| Trouble shoot/ experiment with the process |

This raises a question. If skills are built through practice in relatively stable environments, how can one build process improvement capacity – the skill of exploring and experimenting in high-variety environments? Answering this question led to the recognition that there is an intermediating method of building process improvement capacity. Experimentation is deliberately bounded, not for better practice with the existing techniques or technology, but to provide practice making process changes.

Structuring process improvement efforts to deepen problem solving skill requires that managers reshape their role. In doing so, managers will respond correctly to Hayes and Pisano (1994), who admonished operating managers to lose infatuations with “one best way” and “best practice benchmarking.” Such strategies, they argued, were built to fail, as they could not provide operations-based competitive advantage. Rather, they suggested, it was essential for managers to develop “dynamic capabilities” so that their organizations could adapt to and exploit changes in the competitive environment. That’s precisely what this paper is about.

The process being studied contributes directly, and sometimes spectacularly, to organizational success. We chose Toyota as a research site precisely because of the business success which seems to be significantly attributable to Toyota’s excellence at building process
improvement capacity. In fact, such a capacity can manifest itself as two different kinds of organizational robustness:

- The ability to keep improving current processes, in order to keep ahead of the competition.
- The ability to quickly master and improve new processes when the company has to turn to new activities, which most companies have to do more and more often.

Finally, this research raises and may contribute to answering an even larger question. There are many people in many different positions whose job is to solve problems – ranging from industrial designers to nurses to police detectives to politicians – and the abundance of problems to be solved certainly continues to exceed our collective capacity to solve them. Is it possible to generalize usefully about the common elements of such abilities and how they can developed in more people?

1.3 **Overview of This Paper**

Section 2 explains the choice of research site (Toyota and its affiliates) and the choice of research method (ethnographic).

Section 3 presents a nested, cross-sectional case study from a Toyota-facilitated process improvement effort at MacDougal Automotive. Differences in performance seemed to depend on how each team’s leader framed the exercise. This raised questions about how the highest-performing team’s leader managed the teacher-student relationship with his team members.

Whereas Section 3 conducts a cross-sectional study to identify factors differentiating teams with superior learning capability, Section 4 conducts a longitudinal in-depth case study of how process improvement capability is developed. It begins to answer questions raised in Section 3.

Section 5 concludes the paper by exploring implications of this work.
2 RESEARCH CONTEXT AND METHODS

2.1 TOYOTA: EXEMPLAR OF IMPROVEMENT-BASED COMPETITIVE ADVANTAGE

To understand how process improvement capacity is built, I chose Toyota and its affiliates as research sites because of established links between Toyota’s sustained competitive performance and its problem-solving, learning, and improvement capabilities. For example, in 2001, Toyota led its industry by several measures disproportionate to its market share. Consumer Reports rated Toyota/Lexus first in four of ten product categories. In a 2001 study of initial quality, J.D. Power and Associates rated Toyota/Lexus first in seven of sixteen product categories. Toyota’s Kyushu car plant was rated the best in the world, with other Toyota plants second and third in Asia. In North America, Toyota plants were first and second. Despite industry-wide difficulties, Toyota’s market share and capitalization continued to grow (Burt and Ibison, 2001a, 2001b, 2001c).

Researchers have explained that Toyota’s superior competitive position results from superior improvement processes. For instance, Lieberman, Lau, and Williams (1990) compared growth rates in labor productivity, capital productivity, and total factor productivity for Toyota, Nissan, Mazda, General Motors, Ford, and Chrysler from the 1950s to 1987. Toyota grew all three measures fastest, suggesting that Toyota was learning to use both capital and labor better and more quickly than its competitors, rather than merely improving productivity of one factor by substituting another. Lieberman and Dhawan (2001) estimated auto-industry production possibility frontiers, the theoretical limits with which labor and capital are applied, over three decades. In the late 1960s, major producers clustered around a frontier that was 60% of that in 1997. By 1997, Toyota and Honda had established themselves near the much-improved frontier, separate from American and Japanese competitors. This, too, suggested that superior learning processes were leading to superior performance.

Other researchers have also linked Toyota’s performance to its improvement mechanisms. Adler and his co-authors (1993a, 1993b, 1997) examined how worker-involving, problem-solving
processes at the NUMMI plant, a Toyota Production System (TPS)-managed joint venture with General Motors, provided performance superiority. Fujimoto (1999) found that Toyota exhibited “evolutionary learning,” which he characterized as “an organization’s overall ability to evolve competitive routines even in highly episodic and uncertain situations.” Fujimoto argued that Toyota’s “superior evolutionary learning capability has made a decisive contribution to its high and stable performance.” Spear and Bowen (1999) and Spear (2002) wrote that the result of Toyota’s evolutionary learning is management principles, “Rules-in-Use,” that tightly couple doing work, finding problems in work, and improving work-systems processes in response to problems.

Taken together, therefore, previous research suggests that studying Toyota can provide insights into developing process improvement capacity.

2.2 Ethnography to Understand Work-System Nuances

To understand how process improvement capacity is developed at Toyota, I used ethnographic methods to gather data that I could use to build theory. This followed the precedents of scholars who have argued that, as a prerequisite to building inductive-theories of how social processes truly operate, participation, observation, and interview must be used to study complex social systems. (As we will see, these same techniques of drawing information directly from a process are essential in understanding and improving work processes as well.) Ethnographies, for example, have been used to articulate social structure and dynamics in an immigrant Boston neighborhood (Whyte, 1993), religious communities (Heilman, 1984, 1992), and medical practices (Barley, 1986, 1990). Classic works, such as those by Barnard (1938), Roethlisberger (1942), and Parker-Follet (1940), were grounded in each author’s self-reflective participation or close-hand, sustained observation.

I used direct observation, unstructured interview, and document review to capture the nuances of behavior, method, and outcome as the first step in an inductive process of description, classification, and theory building outlined by Kaplan (1994). Detailed documentation protected
the data and analysis from becoming overly subjective. Thus, analysis was not based on recollections that faded with time, and data as well as analysis could be shared with subjects and colleagues to ensure validity.

For Section 3 of this paper, I gathered data at MacDougal Automotive, where I directly observed a three-day process improvement exercise in order to understand in greater detail how Toyota manages and teaching process improvement. This exercise was part of an 18-month MacDougal-Toyota collaboration, during which I visited the company 10 times for 14 days total.

Section 4 follows the experience of the pseudonymous “Bob Dallis.” Upon joining Toyota, but before receiving his managerial assignment, Dallis was first trained for six months by experienced Toyota people. To understand the nature of Dallis’s development, I spoke with him approximately once a week for an average of 90 minutes per conversation, developing a narrative of his experience which was supplemented by diagrams, reports, and other artifacts.
3 CASE STUDY #1: IMPROVING PROCESSES VERSUS IMPROVING PEOPLE

3.1 INTRODUCTION

This study gave me a chance to observe an attempt at process improvement as it was happening, and, through it, I was able to detect some differences in methods and outcome. For instance, this study provided strong evidence that (1) leading employees in the effort to improve existing manufacturing processes and (2) teaching employees to become more adept at process improvement are two different skills which achieve different results. There is a difference between improving processes and improving the people who can then go on to improve processes. This naturally raised the question of how the latter is accomplished. However, due to the exploratory nature of this investigation and of the data collection methods I used, I lacked sufficient clarity to establish causal links between behavior and results. Fortunately, case study #2, discussed in Section 4, will help establish that.

3.2 THE SITUATION AT MACDOUGAL

MacDougal employed 200 people and generated $20 million in sales by re-manufacturing broken starter motors and alternators that were acquired from auto service centers and that were then repaired and sold to auto-parts distributors. Re-manufacturing involved disassembly, cleaning, repair, re-assembly, packaging, and shipping and was done on ten lines, each dedicated to a product family such as Chrysler alternators, Ford starter motors, and so on. Demand spiked sharply in cold weather, which was hard on starter motors, and hot weather, which placed air conditioning burdens on alternators. Large fluctuations in demand plus process input unreliability (broken components acquired from service centers) meant that MacDougal had to have a broad and deep inventory. Reducing the burden of excess inventory while improving responsiveness to customer needs was the company’s motivation to seek help from Toyota.

MacDougal cooperated with Toyota production experts for 18 months to discover how to raise quality, reduce cost, and shorten response times to customer orders. During that time, from one to five Toyota representatives visited every month or two, for one to three days. While at
MacDougal, they helped the company rationalize material flows, make information exchanges more simple and reliable, and improve individual processes. Between visits, the company was expected to make improvement efforts on its own.

Throughout the 18-month MacDougal-Toyota collaboration, I was a direct observer, visiting the company 10 times for 14 days total.

In particular, I observed a three-day process improvement exercise that included six people from the Toyota Supplier Support Center (TSSC) and nine from MacDougal. These 15 were formed into five teams. Each team had a Toyota leader, and a senior (supervisor or manager) and a junior (operator level) MacDougal person as team members (Team-4 had only a junior MacDougal person). The sixth Toyota person coordinated the whole exercise.

3.3 Observations of an Effort to Build Process Improvement Capacity

The five teams had the same assignment: study the assembly cell, determining work content and cycle time for 12 process steps; implement improvements for a subset of steps; and report what had been accomplished. Below are some of the observations I made during each of these steps and after the assignment had been completed:

While the teams studied the processes they were going to try to improve, I observed:

• **Proximity of team leaders to team members.** Prior to the process improvement exercise at MacDougal, I had learned that in *production settings* Toyota team leaders work in close proximity to team members whom they are assisting, so that when team members have problems or need guidance in completing production tasks, team leaders are immediately available. Now, at MacDougal, I wanted to see how the TSSC team leaders

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2 TSSC supported Toyota Production System implementations at Toyota’s North American suppliers and at other companies, like MacDougal, that were otherwise unaffiliated with Toyota.

worked with the MacDougal team members in a *process improvement setting*. Therefore, for 50 minutes, while each team calculated cycle times for the assembly cell’s twelve process steps, I kept track of where each person was standing, to determine who was working with whom, doing what. For instance, I noted that at 11:05 a.m., the Leader of Team-2 was at the test stand with the two MacDougal team members. At the same time, Team-5’s leader was at Process-2 while Team-5’s senior and junior members were at Process-1. I then calculated the percentage of times that the team-leader was with the senior and junior team members. At the extremes, Team Leader-2 was with his MacDougal person for all of the observations, while Team Leader-5 was with the senior and junior members of the team only 9% of the time. The other leaders were with their teams approximately three-quarters of the time. (See Figure 2 and Figure 3.)

- **Quality of the reported data.** Each team was supposed to calculate the cycle times for each of the twelve production steps. The same two teams were at the extremes: Team-5 recorded times at only three of the stations, whereas Team-2 recorded times at all twelve. The other three teams captured, on average, about 60% of 12 cycle-times. In addition, I noted that Team-2’s calculations were closest to those gathered by the exercise coordinator, whereas Team-5’s were the farthest. (See Figure 2 and Figure 3.)

- **Quality of the observation experience.** When the coordinator asked what the group thought of the exercise, Team-2’s MacDougal people nodded their heads with satisfaction whereas Team-5’s MacDougal people blurted out, “Traumatic!” I interpreted Team-5’s

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4 During the morning exercise, one member of Team-2 was called away to handle a pressing matter elsewhere in the plant. For this period then, Team-2, like Team-4, had one team leader and one team member.

5 I had worked for five months with the coordinator trying to improve the shop floor operations at a Toyota supplier. In the course of our work there, we had done a number of exercises similar to this one to understand the structure and timing of production work. In that time, I had gained confidence in the coordinator’s abilities to describe and measure well how people worked.
response as expressing the uncertainty and difficulty the team members had experienced in trying to master a new skill without the support of the team leader, and with the inferior result of their fledgling efforts visible to their peers and superiors. (See Figure 2.)

While the teams tried to implement their improvements, I observed:

- **Proximity of team leaders to team members (again).** While each team tried to improve two or three of the 12 process-steps, I again recorded each person’s location for forty minutes, then calculated the percentage of time team leaders spent with team members. Again, there was a discrepancy. At the extremes, Team Leader-2 was with his MacDougal person 88% of the time, while Team Leader-5 was with the senior and junior members of the team only 6% of the time. The other leaders were with their teams from 63% to 75% of the time.

While the teams reported their results, I observed:

- **Who made the presentation.** At the end of the three days, each team had report on what changes it had made and what improvement it had achieved. The teams reported differently. Team-1 and Team-3 appointed a MacDougal person to explain the work that they had done, but, in both cases, these members deferred to the Toyota team-leader to provide most of the explanation. The leaders of teams 4 and 5 did all the reporting themselves. In contrast, MacDougal people did all of Team-2’s presentation, demonstrating the changes they had made and supplementing their presentation with hand-drawn before-and-after diagrams. Team-leader 2 himself played no direct role in the debriefing.

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6 During the afternoon portion of the exercise, the other member of Team-2 was called away to address a pressing issue elsewhere in the plant. However, for the remaining two days of the exercise, both team members participated fully.
After reports were completed, I asked each team leader three questions:

- **What were his accomplishments during the exercise?** Four of the team leaders emphasized changes in process performance, discussing the extent to which they had achieved one-piece flow, reduced cycle times, and removed wasteful activities such as sorting for parts or walking between two places.

- **What he would do the following day if he were managing the cell?** The same four team leaders recommended that the cell manager should make permanent what was temporary, for instance by making from metal what was tested in cardboard and welding what was temporarily taped. But Leader-2 offered a striking alternative. First, he said, he would review the changes with the cell’s workers to know what changes they actually maintained and if the day’s production results matched those of pilots during the three-day exercise. As for making permanent the changes that had been developed, he offered that he might do so the following day *if* he had time and *if* his observations and conversations showed that they had sustained value.

- **What was his professional background?** All five were working temporarily for the Toyota Supplier Support Center (TSSC), but had arrived through different pathways. The leader of Team-2 was the only one who came through Toyota’s Japanese operations. He joined Toyota 14 years earlier and worked in production engineering, in Japan, as a tooling specialist. After nine years, he explained, he moved to the Miyoshi plant’s Machining and Manufacturing Engineering Division where he “learned the operator’s point of view”, “always on the shop floor” responsible for equipment maintenance and new product introductions, for five more years. Then, he spent six months in Toyota’s Operations Management Consulting Division (OMCD) refining

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7 OMCD is an elite organization within Toyota. It promotes the Toyota Production System at Toyota and supplier plants in Japan, and its members are considered to have the highest level of TPS knowledge. OMCD was created by Ohno, one of the primary developers of TPS, and a majority of
his problem solving and teaching skill by supporting process improvements at Miyoshi and at two supplier plants in Japan. The other team-leaders all had worked for Toyota in North America only. Team leader 3 worked for a Toyota supplier for almost twenty years and had worked at TSSC for a year. Team leader 4 worked at a Toyota subsidiary in California for 15 years and was doing projects part-time to prepare for a new assignment. Team leader 1 was from another North American Toyota plant and had been doing process improvement work with TSSC for less than six months. Team leader 5 had been a ten-year employee of the Toyota/General Motors NUMMI joint venture but had only been engaged in process improvement with this Toyota group for six months.

3.4 **ANALYSIS OF THE PROCESS IMPROVEMENT STUDY**

I now had several data (Figure 2) about the interaction between team leaders and team members in a process improvement rather than in a production situation. Of these, four – percentage of processes for which cycle times were calculated, the calculations’ accuracy compared with those of the exercise coordinator, team member comfort with the exercise, and who presented on day three – represent intermediate outcome measures. The first measures work completeness, the second, work accuracy, the third, emotional comfort, and the fourth seemed to indicate understanding that had been transferred to the team members. Two sets of data are *behavioral* – how much time team leaders spent with team members in the morning and afternoon of day one. Two are *attitudinal* – self reported accomplishments and recommended next-steps – and one is *historical*, the team leaders’ work backgrounds.

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Toyota’s plant managers and senior leadership have had OMCD experience at least once in their careers. (Source: Interviews with OMCD managers and consultants.)
Building process improvement capacity

Figure 2: Summary of observations

<table>
<thead>
<tr>
<th>Observation</th>
<th>Data type</th>
<th>Team</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Time with T/Ms: Day 1 a.m.(*)</td>
<td>Behavior</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>2. Time with T/Ms: Day 1 p.m.(*)</td>
<td>Behavior</td>
<td></td>
</tr>
<tr>
<td>3. Accomplishments</td>
<td>Attitude</td>
<td></td>
</tr>
<tr>
<td>4. Next steps</td>
<td>Attitude</td>
<td></td>
</tr>
<tr>
<td>5. Professional background</td>
<td>History</td>
<td></td>
</tr>
<tr>
<td>6. Recorded cycle times - Day 1</td>
<td>Outcome</td>
<td></td>
</tr>
<tr>
<td>7. Cycle time accuracy</td>
<td>Outcome</td>
<td></td>
</tr>
<tr>
<td>8. Team/mem. experience</td>
<td>Outcome</td>
<td></td>
</tr>
<tr>
<td>9. Who reported results</td>
<td>Outcome</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Type</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Time with T/Ms: Day 1 a.m. (*)</td>
<td>Behavior</td>
<td>76%</td>
<td>100%</td>
<td>78%</td>
<td>74%</td>
<td>9%</td>
</tr>
<tr>
<td>2. Time with T/Ms: Day 1 p.m. (*)</td>
<td>Behavior</td>
<td>75%</td>
<td>88%</td>
<td>63%</td>
<td>75%</td>
<td>6%</td>
</tr>
<tr>
<td>3. Accomplishments</td>
<td>Attitude</td>
<td>Performance emphasis</td>
<td>Performance emphasis</td>
<td>Performance emphasis</td>
<td>Performance emphasis</td>
<td></td>
</tr>
<tr>
<td>4. Next steps</td>
<td>Attitude</td>
<td>Make changes permanent</td>
<td>Test changes w/ operators</td>
<td>Make changes permanent</td>
<td>Make changes permanent</td>
<td>Make changes permanent</td>
</tr>
<tr>
<td>5. Professional background</td>
<td>History</td>
<td>Toyota N. America + TSSC</td>
<td>Toyota Japan + OMCD + TSSC</td>
<td>Toyota N. American supplier + TSSC</td>
<td>Toyota N. America + TSSC</td>
<td>Toyota N. America + TSSC</td>
</tr>
<tr>
<td>6. Recorded cycle times - Day 1</td>
<td>Outcome</td>
<td>58%</td>
<td>100%</td>
<td>58%</td>
<td>67%</td>
<td>25%</td>
</tr>
<tr>
<td>7. Cycle time accuracy</td>
<td>Outcome</td>
<td>Moderate</td>
<td>High</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>8. Team/mem. experience</td>
<td>Outcome</td>
<td>Okay</td>
<td>“Traumatic”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Who reported results</td>
<td>Outcome</td>
<td>Team member &amp; leader</td>
<td>Team members</td>
<td>Team member &amp; leader</td>
<td>Team leader</td>
<td>Team leader</td>
</tr>
</tbody>
</table>

(*)T/M = Team members.

Team-2 outperformed the others by the outcome measures of quantity and quality of cycle-time calculations, quality of experience, and team member understanding, and this team’s performance appeared to be correlated with differences in behavior and attitude among the team leaders. For example, compare the percentage of time the team leaders were with their juniors on the first assignment and the percentage of process cycle-times each team was able to calculate that morning. As Figure 3 shows, teams that divided more actually conquered less.
Figure 3: Time together and work-elements studied

Team Leader-2 differed from his colleagues in more than the proximity he maintained to his team members. His attitude towards the exercise also differed from theirs. Whereas the other team leaders emphasized performance gains in reporting what they had achieved and what they recommended, he viewed the exercise more circumspectly, as one step – subject to ratification by the process operators – in a continuing improvement effort.

3.5 Questions raised but not answered by these observations

However, what went unobserved during the exercise was as compelling as what I had been able to record.

- While I had gotten some measure of proximity of team leaders to team members, I had not documented closely the nature of the relationship during the exercise, how the different team leaders managed the experience of their team members. Team Leader-2, for instance, may have maintained close proximity to engage the MacDougal people in their specific observations and improvement ideas in the context of the particular process-step on which they were working. However, I could not know that for sure.

- Team-2’s MacDougal people reported their accomplishments to the group, the only MacDougal people able to do so, suggesting that the process improvement exercise, had
been integrated with a skill-developing experience. It was possible that Team Leader-2 was actively coaching them as they practiced basic elements of process improvement, such as observation, analysis, experimentation, and reflection. But, again, I did not know.

- Had Team Leader-2’s professional experience contributed to what appeared to be his superior process improvement and teaching skills and shaped his attitudes about framing process improvement events? I knew that he had gained his experience in a different location (Japan versus USA) than did his counterparts, with shop floor experience complemented by a short tenure in Toyota’s elite Operations Management Consulting Division. Yet, I did not have detailed insight into his professional development.

To summarize then, the MacDougal exercise raised several key questions about building process improvement capability:

- If differences in team member learning are explainable by how the team leaders managed the process improvement exercise, then what was the nature of the team leader-team member relationships during the three days? What went on within Team-2 that could explain its distinctive performance?

- If we explain the difference in outcome by differences in team leader skills, then how did Team Leader-2 acquire his skills at teaching process improvement?

Fortunately, a subsequent opportunity for ethnographic study of Toyota’s process improvement practices allowed deeper exploration of how the skills of a senior person such as Team Leader-2 were developed and how he learned to develop the process improvement capabilities of a junior person. This is recounted in section 4.
4 CASE STUDY #2: DEVELOPING A MANAGER’S PROCESS IMPROVEMENT CAPABILITIES

4.1 INTRODUCTION

Case #1 strongly suggested that the right kind of management, or guidance, is key to developing, or increasing, the capacity for process improvement in employees. In Case #2, we are lucky enough to see what that kind of management looks like in action. In the case of one individual, who is convinced that his capacity for process improvement was greatly increased, we can see what he was taught and how he was taught it.

The pseudonymous ‘Bob Dallis’ was a star at his previous employer. With undergraduate and graduate engineering and business degrees from top universities, and with extensive shop floor management responsibility, Dallis ascended rapidly. In only a decade, he managed an assembly plant, the design of an engine and of the factory that would make it, and the plant ramp up. Nevertheless, Dallis left his employer when corporate turmoil made long-term prospects unclear. He joined Toyota expecting that he would have a senior role in a North American assembly plant. Despite his background and achievements, Dallis did not receive immediate operating responsibility. Rather, “Mike Takahashi,” an eighteen-year Toyota employee and a former manager at a Toyota engine plant in Japan, who had also worked in Toyota’s Operations Management Consulting Division before joining the Toyota Supplier Support Center as a manager, first coached Dallis in improving production processes.

4.2 DESCRIPTION OF DALLIS’S TRAINING

Dallis’s training consisted of the following segments:

- Twelve weeks improving a 19-person assembly process in a North American engine plant. This had two components:

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8 Data in this section is from interviews with “Dallis” done weekly during his overall training and daily during his ten-day training in Japan, described below.
Building process improvement capacity

- Six weeks improving labor productivity.
- Six weeks improving machine productivity.

- Ten days in Japan. This also had two components:
  - Three days improving a machining process with very quick iterations.
  - Additional visits to plants, in which he observed the process improvement efforts of group leaders and the role of more senior managers in building process improvement capacity.

- Developing an improvement plan for the assembly process at the North American engine plant where he had been training for the first twelve weeks.

4.2.1 SEGMENT 1: IMPROVING AN ENGINE ASSEMBLY PROCESS

4.2.1.1 IMPROVING LABOR PRODUCTIVITY

Dallis spent six weeks at a North American engine plant, where there was a project to improve labor productivity\(^9\), ergonomic safety, and operational availability\(^10\) for a 19-person assembly line. First, Takahashi had Dallis observe people directly to discover the detailed nuances of the work-element content, sequence, and cycle-time of each for the line’s 19 processes as the basis for rebalancing work, reducing labor content, and improving ergonomics.

Each day, Dallis worked with the line’s operators, its team leaders, and its group leader. This daily work was bracketed by meetings with Takahashi each Monday and Friday. On Monday, Dallis explained how he thought the assembly process worked, based on his previous week’s observations and experiences; what he thought the line’s problems were, and what changes he had

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\(^9\) Dallis had been hired as a senior manager in one Toyota plant. Dallis’s initial 12 weeks of training and the training he did right upon returning from Japan were in a second Toyota plant, not the one in which he would ultimately work.

\(^10\) Labor Productivity = Labor hours per engine.

\(^11\) Operational availability = machine run-time/use-time. For instance, if a machine required eight minutes of actual process time to grind a surface but, because of jams and other interruptions, ten minutes were required from start to finish, then operational availability would be 80%.
in mind to remove those problems from the system. At week’s end, Takahashi reviewed what
Dallis had actually done and the changes he had actually achieved, comparing these actual events
with the plans that had been set on Monday.

During those six weeks, Dallis made 25 changes. For example, some parts racks were
reconfigured to present material to the operators more comfortably, and a handle on a machine
was repositioned to reduce wrist strain. In addition, Dallis generated 75 other recommendations
for redistributing work-elements across processes. These were more substantial system changes;
it would require greater collaboration to put them into effect. For instance, changing the point
where a part was installed required relocating material stores and moving light curtains, which
provided safety and quality tests, along with their attendant wiring and computer coding. These
changes were made in a single weekend, with the help of technical specialists from the
maintenance and engineering departments, while the plant was otherwise closed. Dallis and
Takahashi then spent the next week studying the assembly line to see if the effects that Dallis
had expected from the changes actually occurred. (This is exactly what Team Leader-2 in the
first case study said he would have done.) They discovered that productivity and ergonomics had
improved significantly, as they had predicted, but operational availability had gotten worse, as
shown in Figure 4.

Figure 4: Before and after comparison of assembly line’s performance

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Productivity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of operators</td>
<td>19</td>
<td>15</td>
</tr>
<tr>
<td>Cycle time</td>
<td>34 seconds</td>
<td>33 seconds</td>
</tr>
<tr>
<td>Total work time/engine</td>
<td>661 seconds</td>
<td>495 seconds</td>
</tr>
<tr>
<td><strong>Ergonomics (*)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red processes</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Yellow processes</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Green processes</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td><strong>Operational availability</strong></td>
<td>≈ 85%</td>
<td>≈ 80%</td>
</tr>
</tbody>
</table>

(*): Process ergonomics were rated from worst (red) to best (green) based on a formula that
considered weight lifted, reaching, twisting, and other risk factors.
4.2.1.2 IMPROVING MACHINE PRODUCTIVITY

Takahashi then reoriented Dallis’s efforts from work methods, largely an operator issue, to operational availability, largely a machine issue, for six more weeks. Dallis had to watch individual machines until they faulted, so that he could investigate causes immediately. While work methods on the assembly line had been repeated nearly twice a minute, machine failures were far less frequent and were often hidden inside the machine. And while the human operators could converse, alas, the machines could not.

Gradually, Dallis identified subtleties that caused interruptions. For instance, one worker loaded gears in a jig, which he then moved into a machine that would tighten the assembly. If he inadvertently tripped the trigger switch before the jig was aligned, the machine faulted, so Dallis had the maintenance department relocate the switch to reduce the likelihood of this error. Another operator pushed a pallet into a machine. After investigating several faults, Dallis realized that the pallet could ride up onto a bumper in the machine, misaligning, so he had the maintenance department replace the bumper with one that had a different cross-section profile. Direct observation of the machines, root-cause analysis with each fault, and immediate reconfiguration to remove suspected causes raised operational availability to 90%, though still below the 95% target.

4.2.2 SEGMENT 2: UNDERSTANDING PROCESS IMPROVEMENT CAPACITY AT TOYOTA-JAPAN

4.2.2.1 IMPROVING A MACHINING PROCESS QUICKLY

Dallis and “Dan Tropp,” another new managerial hire, now accompanied Takahashi to a Toyota engine plant in Japan. This plant, in which Takahashi himself had worked, had a long history, an established workforce, and a world-class reputation. Dallis and Tropp were each to work with one team member operating a machining cell and were each to make 50 improvements in three days.12 Their specific objective was reducing the “overburden” on the worker – walking, walking,
lifting, and other effort that didn’t add value to the product but which did tire or otherwise impede the worker and lengthen cycle times.  

Dallis employed the lessons he had learned from Takahashi in the North American plant. He spent the first three hours on day one observing the team member. By the shift’s end, Dallis had generated seven ideas, four of which he had implemented, but he learned from Takahashi that two team leaders who were having the same training in nearby cells had generated 28 and 31 change ideas, respectively. (These were people with jobs far less senior than the one Dallis had at his previous employer and for which he was being prepared at Toyota.) Dallis realized that his priority on day two was to generate many ideas, reject some with the team member, then trial the others very quickly. By 11 a.m. on the second day, Dallis had built his list to 25 ideas. Takahashi visited the cell periodically, first asking what Dallis was working on, and then providing guidance by asking, “Did you notice this?” or “What do you make of that?” “Before I could give a speculative answer,” recalls Dallis, “he sent me to look or try for myself.”

years of experience, had mastered several jobs, and had roles such as training team members, assisting team members when they had problems, and leading basic process improvement efforts. Group leaders had several more years of work experience and were responsible for developing team leaders, assisting with problems that were beyond the team leaders’ skill, and leading more sophisticated, often cross-disciplinary process improvement efforts, in concert with their counterparts in material conveyance and maintenance. According to Takahashi, who had previously been a manager in this plant, the expectation was that group leaders would spend 70% of their time doing process improvement work. (To the extent that this time would be shared among three to four teams, this would imply that team leaders were expected to spend a minimum of 20% of their time on improvement work.)

Dallis speculated that the logic of starting with “overburden” was to build buy-in on the part of the team member who was being asked to do his regular work while being interrupted by a stranger with whom he did not speak a common language. There is semantic significance in this phrasing. Focusing on “overburden” emphasizes the impact of the work design on the person. In contrast, focusing on “waste” opens the possibility that the person is the problem.
Building process improvement capacity

Dallis felt that his ability to understand and resolve issues grew with practice, so that by the second shift of the second day, and the morning of the third, Dallis was addressing layout issues within the cell, not just the details of individual work elements. He described an example:

There were two machines, with gauges and parts racks. A tool change took eight steps on one and 24 on the other. Was there a better layout that would reduce the number of steps and time? I talked the idea over with the second shift operator. He liked the idea but agreed a lot would be needed to make it happen. We figured out how to simulate the change before getting involved with heavy machinery to move the equipment for real.

When the time was up, Dallis had identified 50 problems with quality checks, tools changes, and other work in the cell. For these problems, he had made 35 changes, with 15 suggestions still to be implemented. (See Figure 5.)

Figure 5: Summary of 50 changes made by Dallis in the machining cell

<table>
<thead>
<tr>
<th></th>
<th>Quality checks (*)</th>
<th>Tool changes (*)</th>
<th>Other work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of changes</td>
<td>Walking</td>
<td>Reaching</td>
<td>Other</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>Effect of changes</td>
<td>20 meter reduction (50%) per check</td>
<td>2 meter reduction</td>
<td>Remove trip risk, organize tools to reduce confusion risks, etc.</td>
</tr>
</tbody>
</table>

(*) Quality checks were performed two to three times an hour and tool changes were done once an hour. Together then, these changes cut approximately one-half a mile of walking per shift for the operator in addition to reducing ergonomic and safety hazards.

Dallis and Tropp concluded their exercise by presenting their work to the plant manager, the machine shop manager, and the shop’s group leaders. They had to make explicit the links between the changes they had made and the impact those changes had on work. One means of reporting these causal links was the logs they kept for the three days. These logs listed operations in the cell, the individual problems Dallis and Tropp had observed, the countermeasure for each problem, the effect of the change, and the reaction to the countermeasure.
of the first and second shift workers. (See Figure 6 below.) Photographs and diagrams complemented the descriptions. “During the presentations,” Dallis reported, “the plant’s general manager, the machine shop’s manager, and its group leaders were engaged in what the “lowly” team leaders said. Two-thirds actively took notes during the team leaders’ presentations, asking pointed questions throughout.”

Figure 6: Excerpts from Dallis’s log

<table>
<thead>
<tr>
<th>Problem #</th>
<th>Location</th>
<th>Description</th>
<th>Countermeasure</th>
<th>Result</th>
<th>Date</th>
<th>Shift 1 reaction</th>
<th>Shift 2 reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Station 6R</td>
<td>T/M walks 4 meters to get and then return first-piece check gauge during tool changes.</td>
<td>Move first-piece check gauge from table to shelf between station 5 and 6.</td>
<td>4 meter reduction in walk/tool change.</td>
<td>May 8</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>58</td>
<td>Part gauging area</td>
<td>T/M walks 5 steps to return cams to return chute, walking around light pole.</td>
<td>Remove light pole (obstruction) and move part gauge 45°</td>
<td>Reduce walk 2 steps</td>
<td>Not done</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

4.2.2.2 LEARNING ABOUT OTHER PROCESS IMPROVEMENT EFFORTS IN JAPAN

Before departing Japan, Dallis and Tropp were taken by Takahashi to several plants to understand how group leaders managed a variety of improvement projects. These included reducing changeover times and establishing a more even production pace for an injection molding process, reducing downtime in a machining operation, and improving productivity and quality activity in final assembly. In the plants Dallis visited, the group leaders who managed the improvement project made the presentations, explaining the problems they were addressing, the process by which they had developed countermeasures, and the effect these countermeasures had on performance. Dallis explained that the group leaders were not just showing the performance improvements. Rather, they were elucidating the means by which the improvements were
Building process improvement capacity

gained, thereby revealing the “experiments” they had been conducting, much as Takahashi had made Dallis do at the end of his three-day training event.

One presentation took place in the engine plant in which Dallis had been working. He and Tropp were shown a project meant to enhance proactive maintenance. There, the concern was that machine reliability was compromised by problems that became evident only when failures occurred. In response, the shop’s group leaders had removed opaque covers from several machines so that operators and team leaders could see and better hear the inner workings of the devices, thus gaining experience by which they could anticipate more accurately and more quickly that machines were going to have difficulties.

4.3 Analysis: What was Dallis Taught during Training Segments One and Two?

Having described Dallis’s experience in the first two segments of Dallis’s training, we will now focus on what he was taught to do and how he was taught to do it. Dallis learned two overall lessons about the development of process improvement capacity:

- How to improve processes.
- The role of the manager in teaching people how to improve processes.

4.3.1 How to Improve Processes

The style of process improvement which Dallis learned consists of asking three questions and taking the actions necessary to answer them. After presenting the questions, we will examine the methods by which they are answered.

The Questions:

1. **How does this process work now?** That is, how does the worker, or the machine, work? This question is answered by making observations and using other methods to draw information directly from the process (or person) as work is being done.

2. **How do I structure changes in the process as experiments?** This question is answered by proposing a hypothesis about how the process works, predicting as precisely as possible what difference a given change in the process will make, making the change, and
observing as precisely as possible what difference it made. The point, again, is to learn directly from the process itself as work is being done.

3. **How do I experiment with maximum frequency, in order to learn more quickly?**

This question is answered by *testing many ideas as quickly as possible*. This aim is furthered by *prototyping changes in as many cases as possible*. The focus on many quick experiments, rather than on a few experiments with a lot of planning and forethought, puts the emphasis, yet again, on learning about the process by drawing as much information directly from the process as possible, as the process operates.

Underlying these questions and the way they are to be answered are *humility* and *respect*, an acknowledgment that you, the intervening manager – the hopeful problem-solver and process-improver – do not fully know how the process works and therefore need to learn *from* the process – from the workers and machines carrying it out.

Perhaps another way to put it is that the process improver does not come to conquer or defeat a problem, but to learn something from the process and then to act accordingly to improve it. At one point, in fact, Takahashi rejected 10 of Dallis’s proposed improvements because he felt that Dallis had not really understood a problem and its causes.

**Answering the Questions:**

Let’s look in more detail at what Dallis learned about the methods by which these questions are best answered:

1. **Make direct observations.**

Researchers have found that process improvement occurs best through problem solving that is done close in time, place, process, and person to the occurrence of “interferences” (von Hippel and Tyre’s phrasing) or “contingencies” (Jaikumar and Bohn’s phrasing) that are discovered by using processes in context.
Building process improvement capacity

All through Dallis’s training, he is required to sit there and watch the employee work or the machine operate. He is not asked to “figure out” why the machine is failing, as if he were a detective solving a crime that had already been committed, but to sit and wait until he can directly observe its failure – that is, to wait for it to tell him what he needs to know. One shop’s group leaders had removed opaque covers from several machines so that operators and team leaders could see and better hear the inner workings of the devices, thus gaining experience by which they could anticipate more accurately and more quickly that machines were going to have difficulties. The point was not for the operators to learn how to “outsmart” the machines, but for them to learn to hear what the machines could tell them.

During the three-day process improvement training in Japan, in fact, no one translated for Dallis and the cell’s team member. They communicated through the physical environment or through models, drawings, and role-playing representations of it.

This approach is in contrast to various kinds of indirect observation such as reports, interviews, surveys, narratives, aggregate data, and statistics. Not that these indirect approaches are wrong or useless. They have their own value, and there may be a loss of perspective (the big picture) when one relies solely on direct observation. But direct observation is essential and no combination of indirect methods, however clever, can take its place.

2. Construct attempted improvements as experiments.

In the classic scientific method, the purpose of an experiment is to test an hypothesis, not just to “see what happens.” The results of the experiment are then used to refine or reject the hypothesis. Dallis’s problem solving was structured as experiments so that he made explicit and testable the assumptions that were imbedded in his analysis of and correction of work. Throughout his training, Dallis had to explain gaps between predicted and actual results, as summarized in Figure 7 below. For instance, in Japan, Dallis had to present the changes he had made as tests of causal relationships, stating the problem he saw, the root-cause he suspected, the change he had made, and the actual effect the countermeasure had on performance, as in
Figure 6, above. His Monday and Friday meetings with Takahashi also required him to propose hypotheses (on Monday) and the results of his experiments (on Friday).

Figure 7: Process improvement: problem solving in context, as experiments

<table>
<thead>
<tr>
<th>Training phase</th>
<th>Data source</th>
<th>Improvement as an experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work methods in N. American plant</td>
<td>• Direct observation of assembly line workers</td>
<td>• Monday-Friday review cycle with Takahashi of what was expected and what had actually occurred</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Review with Takahashi to compare predicted and actual consequences of making 75 changes to the assembly line.</td>
</tr>
<tr>
<td>Machine reliability in N. American plant</td>
<td>• Direct observation of machine faults</td>
<td>• Making changes in machines and testing actual consequence.</td>
</tr>
<tr>
<td>Machining cell in Japan</td>
<td>• Direct observation of production work at machining cell</td>
<td>• Log from Japan training, which linked action and outcome.</td>
</tr>
<tr>
<td></td>
<td>• Practicing wrap-up presentation where the actual presentation was to occur.</td>
<td>• Feedback from senior managers, Takahashi, and shop’s group leaders.</td>
</tr>
<tr>
<td>Process improvement presentations in Japan</td>
<td>• Removing opaque guards to let operators see and hear processes.</td>
<td>• Presentations by Japanese group leaders who emphasized the experimental structure of their improvement projects.</td>
</tr>
</tbody>
</table>

This approach to process change was like that of Team Leader-2 at MacDougal, who wanted to confirm by the actual experience of the operators that changes made during the exercise produced the expected results. On several occasions, Dallis observed group leaders make presentations by explaining the problems they were addressing, the process by which they had developed countermeasures, and the effect these countermeasures had on performance. These group leaders were not just showing the performance improvements, but the means by which the improvements were gained, thereby revealing the “experiments” they had been conducting.

True, many people trying to improve a process would have some idea what was wrong, some idea why a certain change might help, and some idea of what results they expected. The
difference – and it’s a key one – is in bringing this to the surface and being as precise as possible. For example, any manager might say, “Maybe the parts rack should be closer to the assembler’s hand. If we move it here, I’ll bet it’ll shave a few seconds off the cycle.” Were he to try this and find that it was saved six seconds off, he would probably be quite pleased and consider the problem solved. However, in the eyes of a teacher like Takahashi, such a result would be encouraging, but would indicate that the manager still didn’t fully understand the work that he was trying to improve. Why hadn’t he been more specific about how far he was going to move the rack and about how many seconds, four, for instance, that he expected to save. Then, if the actual savings were six seconds, there would be cause for celebration but also for additional inquiry. Why was his estimate of the result two seconds different than the actual result? What didn’t this person really understand about the work, and why didn’t he have this deeper understanding? With the explicit precision encouraged by Takahashi, even a two second discrepancy could prompt deeper investigation into how a process works, and perhaps more importantly, how a particular person approaches the studying and improvement of processes.

3. Test ideas quickly in practice.

This is a clear example of the approach of overall humility. In short: don’t spend time trying to outsmart the workers, the machines, or the process. Get right to work experimenting so that they can show you what’s wrong both with the process and with your attempt to improve it. This was undoubtedly why Dallis was required to make 50 improvements in three days. Note that Takahashi gave Dallis the resources he needed to act this quickly; for some of his improvements, he had a maintenance team member’s help in moving equipment, creating fixtures, relocating wires and pipes, and otherwise providing skilled trade-work so that he could test as many ideas as possible in practice.

Prototyping or piloting changes is a key to making many quick experiments for the purposes of deepening process knowledge that can be put to use in the form of process improving changes. Prototyping was not considered something for Dallis to do only when making the real change would be expensive, time-consuming, or disruptive. It was to be done in as often as possible.
During Dallis’s work with the machining operation, Takahashi and the shop manager came to the cell to review his ideas and gave tips on piloting his changes before asking support workers to make parts or relocate equipment. For instance, Dallis wanted to rotate some gauges that tested parts. The manager showed Dallis how to make cardboard prototypes to test location, orientation, size, and so on, at low cost and in quick time. They then solicited the second shift worker’s response to the changes Dallis had already made and encouraged him to test Dallis’s other ideas. And team Leader-2 at the MacDougal plant also suggested constructing prototypes using cardboard instead of metal and tape instead of welding.

Before Dallis and Tropp made their presentations at the plant in Japan, Takahashi helped them pick the three or four changes that each was going to highlight, and together they went to the production cell to take digital photographs and make measurements. Then they, and the two team-leaders who had also been training, rehearsed their talks before their audience arrived. Such preparation for a presentation was, of course, quite appropriate, but it also showed how natural the habit of prototyping was for Takahashi. Even presentations were to be prototyped.

4.4 **ANALYSIS: HOW WAS DALLIS TAUGHT DURING TRAINING SEGMENTS ONE AND TWO?**

The second lesson, that the manager’s job is to impart and increase process improvement skills amongst his or her employees, will take us back to the distinctive performance of Team-2 in the MacDougal project. The data from Team-2 suggested that the interaction is largely one of team leader (teacher) guiding the development of the team member (student). As Hayes and Pisano (1994) implied, the task is not to instruct employees on how to copy solutions others have developed, but to equip employees to develop solutions most appropriate to the circumstances in which they find themselves. This is appeared to be what Team Leader-2 was doing, and is clearly what Takahashi was doing.

Takahashi’s role was as a teacher, not a technical specialist. He was teaching Dallis how to improve processes by solving problems in context. He was providing Dallis with frequent
problem-solving opportunities, controlling the degree to which each stage introduced additional novelty to enhance the learning experience.

How do these good teachers do it? They enable their “students” to practice a skill that can’t be practiced in the normal way. Normally, practice means repetition. You can practice playing the same piano scale or setting up the same machine tool over and over, becoming better and better at it. But you can’t practice the same process improvement over and over; once you’ve solved a particular problem, you can’t keep solving it in order to get better at doing so. So how do you “practice” something that can never be the same twice? In Dallis’s experience, we can see the elements of practicing process improvement:

1. Many compressed learning cycles with rapid feedback within the cycles.
2. Controlled (or bounded), incremental increase in novelty/complexity.
3. Guidance by a manager who sees his or her role as that of a teacher. This guidance is largely experiential – putting trainees in a position to experience what they need to know rather than showing or explaining it. But sometimes there was instruction in specific techniques, such as observing an employee at work, or looking for opportunities to prototype change ideas.

Let’s look carefully at how these elements were brought into play for Dallis:

1. **Many Compressed Learning Cycles**

Takahashi managed Dallis’s training so that he had many opportunities to practice process improvement and so that each cycle of practice introduced only moderate additions of novelty or complexity. For instance, at the North American engine plant in which he started his training, Takahashi required that Dallis learn to observe work methods directly during the first six weeks in order to understand the subtleties of what operators did. Six weeks of eight-hour shifts meant that Dallis had up to 23,824 opportunities to observe complete work cycles. Because the scope of his work was limited to a single 19-person line, he had over a thousand chances per person to
see complete work cycles. Dallis’s experience managing two plants at his previous employer might have prepared him to look at issues of greater scale and scope, but had Takahashi given him a project with greater scope, his intense experience of learning to observe would have been diluted. Furthermore, Dallis not only had to observe directly, he had to test his understanding by implementing 100 changes, some local and others systemic.

The same concern for high-frequency, problem solving at the actual worksite was evident when Dallis went to Japan, focusing exclusively on the work on one machinist, testing his understanding by making changes in the operator’s work methods and environment. Whereas in North America he had made 25 changes in six weeks (before the weekend blitz during which 75 were completed), in Japan, he had to make 50 changes in 2 1/2 shifts, which meant an average of one change every 22 minutes. This encouraged Dallis to learn by doing and trying in many small increments, rather than by trying a few large system-design changes. Again, the emphasis was on getting Dallis to observe work actually being done, quickly see where struggles were occurring, then rapidly test in use his understanding by implementing a countermeasure, thereby accelerating the rate at which he discovered “contingencies” or “interferences” in the process he was improving and the countermeasures he was introducing as improvements.

Preparing the presentation in Japan was also a situated, iterative, coached learning experience, as Dallis and the other “students” developed their presentations in a room near the shop floor, then did a trial run on the shop-floor, next to the machining cell where they had been working.

2. Controlled Increases in Novelty and Complexity

In several regards, Takahashi bounded Dallis’s process improvement efforts to facilitate skill development, as summarized in Figure 8 below. For example, experimentation often involves testing multiple factors at different levels to fully characterize first- and higher-order interactions

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14 7.5 hours/shift x 3600 seconds/hour x 5 shifts/week x 6 weeks = 810,000 seconds. 810,000 seconds ÷ 34 seconds/cycle = 23,824 cycles. 23,824 cycles ÷ 19 operators = 1,254 cycles/operator.
among process parameters. Yet, when Dallis was solving problems, particularly at the beginning in the North American engine plant and again in his training in Japan, he did “single-factor” experiments, changing small, individual work-elements rather than taking a system perspective. Furthermore, he was not engaging others in a multi-perspective, multi-context search for optimal solutions. Rather, he was arriving at solutions on his own, albeit with coaching at times.

Throughout his training, Dallis confronted incremental increases in novelty. For example, Toyota did not assign Dallis to a “line position” immediately, despite his extensive experience. Rather, he started training at a plant that was similar to the plant he had managed previously in many ways. Both made similar sized engines, using similar machining and assembly processes. Both plants were less than 10 years old, having less experienced workers and narrow product lines. Thus, what was novel to Dallis, initially, was Toyota’s management system, generally, and its approach to problem solving, specifically. The first stage of training was broken into even smaller increments. Dallis was assigned to an assembly line, not a machining line, and while working on the assembly line, he started with work-method motion issues, only progressing to machine problems once he had developed his observation and problem-solving skills for six weeks. As mentioned earlier, this meant that Dallis was moving from problems that were easier to observe to those that were harder.

After the first twelve weeks, the engine plant in Japan also presented small increases in novelty. Toyota’s problem solving approaches were no longer new, and Dallis and Takahashi had established a relationship, but Dallis was moving to a plant that was more experienced (more than 30 years old), and he was moving from an assembly to a machining operation. However, the scale was kept small – one person in one cell – and Takahashi had worked in the plant, so he could guide Dallis.
Figure 8: Introducing novelty in small increments(*)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Last employer</th>
<th>1&lt;sup&gt;st&lt;/sup&gt; training site</th>
<th>2&lt;sup&gt;nd&lt;/sup&gt; training site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product</td>
<td>Engine</td>
<td>Engine</td>
<td>Engine</td>
</tr>
<tr>
<td>Management system</td>
<td>Toyota’s</td>
<td>Toyota’s</td>
<td></td>
</tr>
<tr>
<td>Processes</td>
<td>Assembly &amp; machining</td>
<td>Assembly</td>
<td>Machining</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1&lt;sup&gt;st&lt;/sup&gt;: Work methods</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt;: Machine problems</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1&lt;sup&gt;st&lt;/sup&gt;: Improve work space &amp; methods</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt;: Learn about machine project</td>
</tr>
<tr>
<td>Plant age</td>
<td>Less than 10 years</td>
<td>Less than 10 years</td>
<td>More than 30 years</td>
</tr>
<tr>
<td>workforce experience &amp; process knowledge</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Problem solving support</td>
<td>Week lead-time for changes</td>
<td>Week lead-times for changes</td>
<td>Changes made in a shift</td>
</tr>
<tr>
<td>Familiarity of plant</td>
<td>Known to Dallis</td>
<td>Known by Takahashi</td>
<td>Takahashi’s former work site</td>
</tr>
</tbody>
</table>

(*): **Bold items** are something novel.

The accessibility of the machining cell was increased since Dallis was directed to work-method issues of “overburden” rather than less accessible machine faults. However, Dallis did not leave the plant without seeing the interaction of man, machine, and method. Rather, he concluded his stay with presentations about team leader-led and group leader-led improvement projects being pursued elsewhere. Even these represented small additions of novelty. Because Dallis had just improved processes first-hand, the explanations provided to him required less extrapolation on fewer factors. With his knowledge deepened, Dallis was able to comment at this point, “As a former engine-plant person, the line I saw was 15 years old but had the capacity to
build 90 different engine-types. It was amazing that they solved so many problems with such simple equipment. Behind the changes was some pretty deep thinking."15

3. Guidance by a Manager/Teacher

Takahashi, like Team Leader-2, positioned himself as a teacher and coach, not as a technological specialist. Dallis, although already an experienced and accomplished manager, was never left to sink or swim. Takahashi accompanied Dallis on his first day to the North American plant and coached Dallis at the start and end of every week there. Takahashi accompanied Dallis and Tropp to Japan, coaching each during their three day exercise and accompanying them to each of the improvement project demonstrations so as to provide context, explanation, and instruction.

On the whole, Takahashi put Dallis through experiences without explicitly stating what he was to learn and how. He would ask Dallis questions such as “What do you make of that?” and “Did you notice this?” and would send his back to the work-site to look and try for himself.

Sometimes, however, specific skills were imparted:

- Takahashi showed Dallis how to observe an individual worker to spot instances of stress, wasted effort, and so on.

- Dallis was explicitly advised on the use of prototypes.

Despite this direction, Takahashi didn’t suggest specific process improvements to Dallis. Rather, he directed him on how to find opportunities for improvement (i.e., study this person or

15 The incrementalism of Dallis’s learning experiences may have both cognitive and emotional elements. On the cognitive side, learning in many small steps may be easier than in few large steps. Another issue is that if each learning cycle is kept small and bounded, then the learner can make mistakes, but there is a floor/lower limit on their downside consequences. Limiting the potential risk for the learner may increase their willingness to learn by doing much as changing the perceived consequences of error reporting altered the rate at which nurses studied by Edmondson (1996) reported work related mistakes.
that machine looking for various types of stress, strain, or faults), and directed him on how to
development and test possible countermeasures.

4.5 SEGMENT 3: RETURNING TO THE NORTH AMERICAN PLANT

Having described and analyzed the first two segments of Dallis’s training, we will return to a
narrative of the third and final segment. We will see that Dallis’s own actions, his interpretation
of his experience as reflected in his actions, are consistent with our previous analysis of what he
had already learned and how he had learned it.

After his training in Japan, but before moving on to the assembly plant to which he would be
assigned, Dallis returned with Takahashi to the North American engine plant in which he had
spent the first 12-week segment of his training. Before his departure to Japan, he had
contributed to substantial improvements in the assembly-line’s labor productivity and ergonomic
safety, as summarized above, in Figure 4. However, Dallis had been unable to raise operational
availability to its target rate of 95%. Now, upon his return to that plant, Takahashi had Dallis
readdress this problem, but Dallis did so informed by his training of the previous months.

Dallis had learned some important process improvement skills. Perhaps more importantly, he
learned how it is possible to practice such skills in order to improve them. Also, he learned how
to teach such skills to someone else by guiding him or her through practice such as he had
experienced. Finally, during his training in Japan, Dallis had observed (and was sometimes
surprised by) the frequency and sophistication with which first-level managers (team leaders) and
second-level managers (group leaders) could improve processes and teach others to do the same.
He had seen that:

• Japanese “group leaders,” who are second-level supervisors, were explaining complex
changes, something their North American equivalents would not have done.

• Despite his fairly substantial experience, he was getting the training given to first-level
Japanese supervisors. Although he had had some 900 people reporting to him in his
Building process improvement capacity

previous job, he was being trained exactly as a supervisor responsible for five to fifteen people.

Dallis returned to the assembly process at the first training plant with an altered focus. It became clear from the way Takahashi managed Dallis’s training, and from what he had seen of others’ training, that the manager’s efforts should produce a cadre of excellent group leaders. He realized now that his job was not, as he might have thought, to improve the processes in his plant, but to teach his group and team leaders to improve the processes. The target of 95% operational availability remained the same, but he now knew whose target it really was, and it wasn’t his.

So, with Takahashi’s guidance, Dallis worked with the line’s group leader and assistant manager to design exercises that would develop the problem-solving skills of the line’s team members and team leaders. The point was for them to learn to “solve little problems, simultaneously, so the line could recover quickly when problems occurred.” Some of the projects included building better visual controls into the work, cross-training operators in new work designs, and modifying machines in which idiosyncrasies had been linked to unplanned stoppages.

Whereas, some months ago, Dallis initially engaged himself in improving the process directly, he now reframed his priority as developing the process improvement capacity of the assembly line by developing the skills of the group leaders who had day-to-day responsibility for the workers and their performance in each area. From his own experience he understood that process improvement skill had to be developed through problem solving, but problem solving that was deliberately structured to foster skill development primarily, and process gains, secondarily.

4.6 Summary

Takahashi had established a “transformative” experience for Dallis, which was reflected in the way Dallis approached his task at the North American engine plant upon his return.
Takahashi managed Dallis’s training with a process not clearly identified in the literature. For instance, Adler and Clark (1991) distinguished between practice with an established process and process improvement. What Takahashi did was to structure Dallis’s experience so that he could practice process improvement. For example, Takahashi emphasized that Dallis use data drawn directly from processes to construct and evaluate structured, hypotheses-testing experiments. This indicates that good process improvement methods were being developed. The volume and frequency of Dallis’s problem solving, and the stability that Takahashi maintained within learning cycles, contributed a “practice” element to Dallis’s training.

The result was that Dallis became a better problem-solver, by his own estimate, with a heightened capacity to observe processes, diagnose them, and construct changes as experiments. Dallis also gained insight into developing other people’s skills, a perspective that found expression in the skill-building-based continuous improvement plan he developed for the assembly line on which he had been training.

In light of this evidence, Figure 1, above, should be modified. It should include another learning mode -- *practicing process improvement*, in addition to the ‘practice’ and ‘process improvement’ learning modes identified by Adler and Clark (1991). This additional learning mode is how Toyota develops its capacity, develops the skill of its people, for engaging in the superlative process improvement for which it has been credited by Adler and his co-authors, Fujimoto, Lieberman and his co-authors, and others, cited above.
Building process improvement capacity

Figure 9: Learning modes that include *practicing process improvement*

<table>
<thead>
<tr>
<th>Method</th>
<th>Context</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practice relationship</td>
<td>Stable process parameters</td>
<td>Master the process</td>
</tr>
<tr>
<td>Use the process as designed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Practicing process improvement relationship

<table>
<thead>
<tr>
<th>Method</th>
<th>Context</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change the process in small, frequent, rapid-feedback increments</td>
<td>Incremental variation in process parameters</td>
<td>Master process improvement</td>
</tr>
<tr>
<td>Trouble shoot/experiment with the process</td>
<td>Increased process improvement capacity</td>
<td>Change/improve the process</td>
</tr>
</tbody>
</table>
5 CONCLUSIONS

This paper began with the observation that two mechanisms had been identified by which learning curves may operate, and that there is an inherent tension between the two. One mechanism emphasizes skill building with an established process and requires frequent learning cycles with little novelty per cycle. The other mechanism emphasizes problem solving and product and process modification. It requires variety in process parameters to find “interferences” and employs multiple perspectives in developing solutions.

We asked how organizations learn to improve processes, and looked to Toyota, a company which has long had high rates of performance improvement, for examples on which to build theory. Thus, the paper ended with the assertion that there is an intermediating process for building process improvement capacity. In this, certain attributes of process improvement are temporarily bounded to enhance the learning experience. For this to occur well, those more senior must:

• Provide volumes of practice.
• Create temporarily stable environments for effective learning.
• Structure practice as experiments with feedback.
• Teach, rather than provide technical solutions.

This invites further exploration. For example:

• Dallis was being trained to draw information directly from the process. What if he were working with a process that did not lend itself well to direct observation?

• Dallis underwent much of his training with processes in which the scope of interaction could be narrowed to a few people or machines. How would someone be trained to improve processes that cannot be so well disaggregated; for example, continuous flow processes such as refining?
Takahashi sacrificed short-term process gains for long-term capability development. Under what conditions might a manager choose to emphasize process change over capability development: unstable workforces, short-lived processes, etc.?

The notion that learning requires incremental novelty begs the question of how to improve “extreme” processes, those that are either so unstable as to provide little replication of inputs and outputs or have so many confounding, interacting causal variables that establishing cause and effect is cognitively overwhelming.

How much difference has training such as Dallis’s made? Under what circumstances has it worked well or produced disappointing results? Have there been any detrimental results?

What are the best ways to institutionalize and perpetuate this capacity, once it is established and understood?

In what ways and to what extent would this approach need to be tailored to the culture of each individual organization?

Dallis was aware that, despite his experience and training, he was being given the same training as group leaders and team leaders considerably below him in the organization’s hierarchy. He displayed a great trust in Toyota generally and in Takahashi specifically by accepting such training without question or protest. Where does such trust come from? Why did Takahashi seem to take such trust for granted?
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Building process improvement capacity


6.2 UNCITED


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