



# MIT Sloan School of Management

Working Paper 4359-02  
March 2002

## ORGANIZATIONAL LEARNING FROM EXPERIENCE IN HIGH-HAZARD INDUSTRIES: PROBLEM INVESTIGATION AS OFF-LINE REFLECTIVE PRACTICE

John S. Carroll, Jenny W. Rudolph, Sachi Hatakenaka

© 2002 by John S. Carroll, Jenny W. Rudolph, Sachi Hatakenaka. All rights reserved.  
Short sections of text, not to exceed two paragraphs, may be quoted without  
explicit permission provided that full credit including © notice is given to the source.

This paper also can be downloaded without charge from the  
Social Science Research Network Electronic Paper Collection:

[http://ssrn.com/abstract\\_id=305718](http://ssrn.com/abstract_id=305718)

**ORGANIZATIONAL LEARNING FROM EXPERIENCE IN HIGH-HAZARD  
INDUSTRIES:  
PROBLEM INVESTIGATIONS AS OFF-LINE REFLECTIVE PRACTICE**

John S. Carroll, MIT Sloan School of Management  
Jenny W. Rudolph, Boston College Carroll School of Management  
Sachi Hatakenaka, MIT Sloan School of Management

Submitted to B. Staw & R. Sutton, Research in Organizational Behavior

Abstract

Learning from experience, the cyclical interplay of thinking and doing, is increasingly important as organizations struggle to cope with rapidly changing environments and more complex and interdependent sets of knowledge. This paper confronts two central issues for organizational learning: (1) how is local learning (by individuals or small groups) integrated into collective learning by organizations? and (2) what are the differences between learning practices that focus on control, elimination of surprises, and single-loop incremental “fixing” of problems with those that focus on deep or radical learning, double-loop challenging of assumptions, and discovery of new opportunities? We articulate these relationships through an analysis of particular learning practices in high-hazard organizations, specifically, problem investigation teams that examine the most serious and troubling events and trends in nuclear power plants and chemical plants. We first distinguish a controlling orientation from a rethinking orientation, and illustrate learning practices with three case studies from the nuclear power and chemical industries and a questionnaire study of three nuclear power plants. We then extend our framework to create a four-stage model of organizational learning: (1) local learning by decentralized individuals and work groups, (2) constrained learning in a context of compliance with rules, (3) open learning prompted by acknowledgement of doubt and desire to learn, and (4) deep learning based on skillful inquiry and systemic mental models. These four stages contrast whether learning is primarily single-loop or double-loop, i.e., whether the organization can surface and challenge the assumptions and mental models underlying behavior, and whether learning is relatively improvised or structured. We conclude with a discussion of the stages, levels of learning (team, organizational, and individual), and the role of action, thinking, and emotion in organizational learning.

**ORGANIZATIONAL LEARNING FROM EXPERIENCE IN HIGH-HAZARD  
INDUSTRIES:  
PROBLEM INVESTIGATIONS AS OFF-LINE REFLECTIVE PRACTICE<sup>1</sup>**

John S. Carroll, MIT Sloan School of Management  
Jenny W. Rudolph, Boston College Carroll School of Management  
Sachi Hatakenaka, MIT Sloan School of Management

To be submitted to Research in Organizational Behavior

Organizational learning has become a familiar yet controversial concept (Argyris & Schön, 1996; Fiol & Lyles, 1985; Mirvis, 1996). While mindful of the dangers of personification, we treat organizations as learning entities to emphasize particular capabilities and processes. This approach may be especially fruitful and timely as organizations struggle to cope with rapidly changing environments and more complex and interdependent sets of knowledge. Most importantly, the concept encourages us to confront two central issues for this paper: (1) how is local learning (by individuals or small groups) integrated into collective learning by organizations (e.g., Crossan, Lane, & White, 1999; Kim, 1993)? and (2) what are the differences between learning practices that focus on control, elimination of surprises, and single-loop incremental “fixing” of problems and those that focus on deep or radical learning, double-loop challenging of assumptions, and discovery of new opportunities (e.g., Argyris & Schön, 1996; Carroll, 1998; March, 1991; Miner & Mezias, 1996; Sitkin, Sutcliffe, & Schroeder, 1994)? We articulate these relationships through an analysis of particular learning practices in high-hazard or high-reliability organizations.

## **BACKGROUND**

### Learning and Knowledge

Learning is typically understood as a description of *individual* human behavior. Humans evolved as adaptive learners with few predetermined behavioral routines beyond what is needed to automatically sustain life. The evolutionary process produces enormous complexity from a few powerful principles: variation through genetic recombination and occasional mutation, selection through reproductive success, retention and diffusion in a population, and struggle over scarce resources (Aldrich, 1999;

---

<sup>1</sup> This research was supported by National Science Foundation grants SBR96-1779 and SBR98-11451 and a Marvin Bower Fellowship at the Harvard Business School. Requests for reprints should be sent to the first author, 50 Memorial Dr., Cambridge, MA 02142. We greatly appreciate the cooperation of the nuclear power and chemical plant sites and the staff of their corrective action programs. Assistance in collecting, coding, analyzing, and interpreting data was provided by Marcello Boldrini, Deborah Carroll, Christopher Resto, Khushbu Srivastava, Annique Un, and Theodore Wiederhold. Dr. William Corcoran provided invaluable insights into the investigation process, the nuclear industry, and the report coding process. We thank Vicki Bier, Bill Corcoran, Mary Crossan, Amy Edmondson, Alfie Marcus, and Jim Reason for comments on earlier drafts.

Campbell, 1969). Analogously, the individual learning process builds upon the same principles: combine behaviors into more complex routines, make occasional errors that may reveal new opportunities (March, 1991; Weick, 1995), repeat what has been successful (“law of effect,” Thorndike, 1911), and compete for attention and other scarce cognitive resources (cf., bounded rationality, March & Simon, 1958).

However, additional characteristics speed up the human learning process: seek novelty (Berlyne, 1960), copy others (vicarious learning, Bandura & Walters, 1963), and imagine possibilities (allowing feedforward<sup>2</sup> predictions, counterfactual thinking, and virtual learning, March, Sproull, & Tamuz, 1991; Morris & Moore, 2000). In numerous ways, human learning is essentially *social*: we learn from and with others embedded in systems of interaction (Weick & Roberts, 1993), get feedback from others, and use language and other socially constructed conceptions and objects to drive our imagination and facilitate the spread of ideas and practices (e.g., Carlile, in press; Lave & Wenger, 1991).

We define *learning* as a change in condition-action linkages, and *organizational learning* as an analogous change at an organizational level. This is similar to Argyris & Schon’s (1996) definition of theories of action as propositions of the form “if you intend to produce consequence C in situation S, then do [action] A” (p. 13). We preserve the form of these propositions but relax the focus on intentional learning to acknowledge that learning can occur without intention or awareness, and even without observable action (Glynn, Lant, & Milliken, 1994). For example, consider a factory producing some amount of product per unit time. During a visit to another factory, organization members observe that similar machines can be run at higher speeds. Yet, after returning to their factory, production remains at the same rate. Until external pressure, a vision, or an intrinsic motive engages new behaviors, there may be no measurable change in performance. Nor does learning have to be an improvement (Crossan, et al., 1995): the factory may speed up in response to competition, yet morale may erode, quality may drop, machines may break down, and the factory may ultimately lose its customers. Learning to do the wrong thing is still learning (e.g., superstitious learning, Levitt & March, 1988). If management decides instead to reorganize the plant into a lean production system rather than simply speeding up the machines and the people, then the factory would need time to try out the new actions and coordinate the various components, thus enacting a learning curve (Argote, 1999). More complex actions with more actors who have to be coordinated would require an iterative process of planning, acting, observing feedback, analyzing and thinking, and adjusting (Argyris & Schön, 1996; Crossan et al., 1999; Daft & Weick, 1984; Kolb, 1984).

Whereas learning is a *process* of change, the *content* of that process, the condition-action linkages, is *knowledge* (broadly construed to include explicit

---

<sup>2</sup> We use feedforward to mean predicting future events from a model or theory of action and feedback to mean comparing outcomes to expectations (e.g., Rasmussen, 1990; Reason, 1997). Crossan et al. (1999) use the same terms differently: feedforward is communicating knowledge from individual exploration to the organization, and feedback is institutionalizing routines to exploit knowledge.

information, tacit know-how, etc.). Organizational knowledge is embodied in physical artifacts (equipment, layout, databases, documents), organizational structures (roles, reward systems, procedures), and people (skills, values, beliefs, practices) (cf., Kim, 1993; Levitt & March, 1988; Schein, 1992). Although organizations may “fill knowledge reservoirs” (Argote & Ingram, 2000) from theoretical principles, by imaginative rumination, or by observing others, enactment or putting this knowledge to use requires combining component-level knowledge and filling gaps by improvisation (Weick, 1998). If the requisite performances are more unfamiliar, tacit, contextual, or contested among stakeholders, then the learning process will be more iterative, unpredictable, and emergent from evolving practice (Carlile, in press; Nonaka & Takeuchi, 1995).

Carrying out these learning activities as an organization involves complex interdependencies across people and groups (Crossan, et al, 1999; Kim, 1993). Different parts of the organization, such as plant operators and corporate executives, “know” different things about how work is done. Their knowledge is contained in different reservoirs (Argote & Ingram, 2000) and expressed in different languages by groups that live in different thought worlds (Dougherty, 1992). Bridging across these groups requires common experiences and common referents, which are developed in bridging practices (Carlile, in press; Cook & Brown, 1999) including cooperative action, shared representations, collaborative reflection, and exchanges of personnel (Gruenfeld, Martorana, & Fan, 2000). These bridging practices are supported by both interpersonal skills such as conflict management (Jehn, Northcraft, & Neale, 1999) and networking across boundaries (Yan & Louis, 1999), cognitive skills such as logical analysis and systems thinking (Senge, 1990), and skills that involve both, such as collaborative inquiry (Isaacs, 1999).

### High-Hazard Organizations

High-hazard organizations such as nuclear power plants and chemical plants have been an important focus of organizational research since the seminal books by Turner (1978) and Perrow (1984). High-hazard organizations are distinctive work settings that include potential harm or death to large numbers of individuals in a single event, such as an explosion or crash. Theory about high-hazard organizations developed further with the work of Rasmussen (1990) and Reason (1990) in psychology, LaPorte and Consolini (1991) and Wildavsky (1988) in political science, and Roberts (1990) and Weick (1987) in management.

The special importance of learning in high-hazard organizations was recognized early in both the research and policy literatures (e.g., the investigation of Three Mile Island, Kemeny et al., 1979). As Weick (1987) stated, “organizations in which reliability is a more pressing issue than efficiency often have unique problems in learning and understanding” (p. 112). Such organizations develop distinct learning strategies (Weick, Sutcliffe, & Obstfeld, 1999) arising from the need to understand complex interdependencies among systems (Perrow, 1984), and avoid both potential catastrophes associated with trial-and-error learning (Weick, 1987) and complacency that can arise

from learning only by successes (Sitkin, 1992). Organization theorists argue vigorously regarding whether high-hazard organizations are distinctive because of the inherent normalcy of accidents (Perrow, 1984; Sagan, 1993; Vaughn, 1996) or because they achieve “high reliability” through special organizational features that allow people to handle hazardous tasks with remarkably few problems (LaPorte & Consolini, 1991; Roberts, 1990; Weick et al., 1999).

Importantly for researchers, these organizations undergo intense public scrutiny, particularly when things go wrong. Investigations of the Three Mile Island (Perrow, 1984), Bhopal (Srivastava, 1987), and Challenger (Vaughn, 1996) accidents, for example, provided rich databases for researchers. Of course, investigators such as Sagan (1993) had to use the Freedom of Information Act to gain access to information on military nuclear weapons mishaps. The post-hoc analysis of accidents has produced a fascinating body of research, limited as it is by a reliance on investigations by others and biases in selection and hindsight (Woods, et al, in press). On-the-ground fieldwork has been more unusual as illustrations and case studies are gathered slowly (e.g., Bourrier, 1999; Perin, 1998; Roberts, 1990).

High-hazard organizations live on the boundary between maintaining control and learning (Sitkin et al., 1994) or exploiting current capabilities while exploring unfamiliar possibilities (Crossan et al, 1999; March, 1991). High-hazard organizations try to anticipate and defend against problems while responding resiliently to surprises (Wildavsky, 1988). On the one hand, such organizations must comply with a large body of regulations and rules to avoid accidents yet, on the other hand, the rules cannot predict every eventuality and humans must still improvise and learn in the midst of action. Weick et al. (1999) argue that maintaining high reliability requires mindfulness consisting of attention to hazards and weak signals (Vaughn, 1996), a broad action repertoire (Westrum, 1988), and a willingness to consider alternatives (March, et al., 1991; Schulman, 1993). They theorize that such “inquiry and interpretation grounded in capabilities for action” (p. 91) is encouraged by distinctive organizational processes, including preoccupation with failure and reluctance to simplify interpretations. They further argue that more and more organizations in our fast-paced world are beginning to resemble high-reliability organizations.

### Our Research Program

Our own work has focused on a particular learning activity carried out by nearly all high-hazard organizations: problem investigations within corrective action programs (Carroll, 1995, 1998; Carroll, et al., 2001; Schaaf, Lucas, & Hale, 1991). Rather than the massive investigations triggered by accidents such as Three Mile Island, we examine the self-analyses and problem solving that follows detection of small defects, near misses, and other lesser failures (Sitkin, 1992) or precursors (Reason, 1990). This problem investigation process is a form of off-line reflective practice (Argyris, 1996; Schön, 1987; Rudolph, Taylor, & Foldy, 2000): sensemaking, analysis, and imagining of alternatives takes place outside of the regular work process, often carried out by individuals who were not immediately involved in the problem itself. Problem investigations are part of a

corrective action program that starts with reporting of problems and continues with investigation of facts and opinions, attribution of causes, generation of insights and recommendations, implementation of interventions to improve performance, and checking that these interventions were actually carried out with the expected results. Although individuals investigate most problems once they are reported, teams handle the most serious, persistent, causally ambiguous, and organizationally complex problems.

Our research program has focused on studies of problem investigation teams at several nuclear power and chemical plants. Problem investigations illustrate how team learning, organizational learning, and individual learning are distinct yet interconnected (Crossan et al, 1999; Kim 1993). Teams are asked to imagine and interpret on behalf of the organization (Huber, 1991). The *team learning* then must be embedded or institutionalized in knowledge reservoirs such as procedure manuals and databases (Argote & Ingram, 2000), physical changes, and altered routines (Levitt & March, 1988). As a partial record of the team learning, the team report feeds a change implementation process and explicit databases intended to capture *organizational learning*. Team learning influences *individual learning* as the team members develop their personal knowledge and skills and bridge their communities of practice (Brown & Cook, 1999). Individual learning indirectly influences organization learning as team members share information with managers and coworkers in the departments to which the team members return (Gruenfeld, et al. 2000).

In this paper, we provide empirical illustrations from three different types of studies. The first type is represented by two case studies of specific problem investigation teams. One case study is based primarily on written questionnaires from team members and managers collected more than a year after the investigation, combined with our own analysis of the team's written report. The other case study is based on direct observation of the team during its investigation process and follow-up interviews with team members and managers several months later, along with analysis of the written report. The second type of study is a quantitative analysis of questionnaire responses from team members and managers involved in 27 investigations along with coding of the written reports. The final case study examines an organizational transformation. Although this diverges from our studies of problem investigations, it represents the same themes of control, trust, and learning at an organizational level. The first author visited this plant regularly as part of a team advising the board of directors, combining first-hand observation, document review, and interviews with a wide range of employees and other key informants over a four-year period of time.

We focus this paper on the differences between a *controlling* orientation and a *rethinking* orientation (cf. "control vs. learning," Sitkin et al., 1994; "fixing vs. learning," Carroll, 1995, 1998). The next section of the paper provides a conceptual discussion of these learning orientations. We argue that it is very challenging for organizations to develop a full range of learning capabilities because assumptions underlying the two approaches can be in conflict and the controlling approach is strongly supported by cognitive biases, industry norms, professional subcultures, and regulatory authority. In the following section of the paper, we present four empirical illustrations of the

orientations in action, using the three types of studies described above. Analysis of the four examples helps us expand the contrast of controlling and rethinking into a *four-stage model* of organizational learning: local, constrained, open, and deep learning. These four stages can be organized according to two dimensions: single-loop vs. double-loop learning, and improvising vs. structuring. Finally, we discuss the implications of our analyses for stages, levels of learning (team, organizational, and individual), and the role of action, thinking, and emotion in organizational learning.

## THE CONCEPTS OF CONTROLLING AND RETHINKING

### The Controlling Orientation to Learning

For most of its history, the nuclear power industry attempted to improve operations and prevent accidents through creation and enforcement of bureaucratic controls (a similar story could be told for many industries). Although all organizations generate standard operating procedures and other formal routines to make work predictable and facilitate coordination (Nelson & Winter, 1981; Levitt & March, 1988; Pugh et al., 1969), “the managers of hazardous systems must try to restrict human actions to pathways that are not only efficient and productive, but also safe” (Reason, 1997, p. 49). Elaborate probabilistic analyses (e.g., US Nuclear Regulatory Commission, 1975) are used to anticipate (Wildavsky, 1988) possible failure paths and to design physical and procedural barriers to these paths.

The controlling orientation attempts to minimize variation and avoid surprises (March, 1991; Sitkin et al., 1994). Compliance with procedures, codes, and standards is enforced by layers of internal and external monitoring and record keeping. Deviations are dealt with by evolutionary enhancements, including more controls: “Safe operating procedures... are continually being amended to prohibit actions that have been implicated in some recent accident or incident” (Reason, 1997, p. 49). Performance is understood as the absence of deviation or error, a *prevention* focus that is associated with anxiety, loss aversion, avoidance of errors of commission, and a strong moral obligation to comply with rules (Higgins, 1998). Learning is understood as a set of routines for training, performance feedback, statistical process control (Sitkin et al, 1994), after action review, procedure revision, and other forms of incremental improvement (Miner & Mezas, 1996). Learning activities are typically separated from everyday work as part of training or a staff specialist function to analyze problems or utilize industry experience. This learning is directed at further control through exploitation of the known rather than exploration of the unknown (March, 1991). We summarize these and other characteristics of the controlling orientation in Table 1, in contrast to characteristics of the rethinking orientation.

-----  
Insert Table 1  
-----

Within the controlling orientation, problems stimulate blame that undermines information flow and learning (Morris & Moore, 2000; O’Reilly, 1978). For example, an inspector from the US Nuclear Regulatory Commission (NRC) criticized one plant after

he discovered a set of informal records of problems without a plan to address each problem. As one manager at a well-respected plant stated, “NRC wants crisp problem identification and timely resolution.” The plant’s response was to stop documenting problems for which there were no immediate action plans, thus ignoring the unfinished nature of current routines (Schulman, 1993) and maintaining the *illusion* of control (Carroll, 1995; Langer, 1975), while possibly decreasing the potential for learning.

The type of learning that is consistent with the controlling orientation is sometimes called *single-loop learning*. Learning is engaged typically by an unanticipated mismatch between expected or desired outcomes and reality (see Figure 1), and feedback is used to adjust actions in order to reduce the gap between desired and actual results and thereby regain control (Argyris, Putnam, & Smith, 1985). In contrast, as we will discuss later, *double-loop learning* goes further to challenge the appropriateness of goals or the basic cultural assumptions and mental models for influencing human behavior and predicting results (Argyris, et al., 1985; Schein, 1992; Senge, 1990). Although single-loop learning is often disparaged in contrast to double-loop learning, most learning is undoubtedly single-loop, and single-loop learning can be very powerful (Miner & Mezias, 1996). Even Argyris (1996) acknowledged that the “routine single-loop features of technical theories also created liberating alternatives. Although they did not create double-loop learning, it appeared that they prevented the need for double-loop learning in the first place” (p. 80).

In striving for control, identifying a presumed “root cause”<sup>3</sup> or source of the mismatch reduces uncomfortable ambiguity (cf. Frisch & Baron, 1988). Causes are found that are proximal to the problem (White, 1988), with available solutions that can easily be enacted, and are acceptable to powerful stakeholders (Carroll, 1995; Tetlock, 1983). Observers commonly make the fundamental attribution error of finding fault with salient individuals in a complex situation (Nisbett & Ross, 1980), such as the operators or mechanics who had their hands on the equipment when the problem arose (Carroll, 1995; Reason, 1990). Decision makers see problems “out there” rather than questioning how their own internal assumptions and beliefs contribute to the structures in which they work (Torbert, 1972). Activities that appeared to be normal before a problem emerged are identified in hindsight as “an accident waiting to happen” (Perrow, 1994, p. 14; Royal Society, 1992; cf., the outcome bias, Baron & Hershey, 1988). Corrective actions usually strengthen control mechanisms (more training, more supervision, more discipline), create more rules (more detailed procedures, more regulatory requirements), or design hazards and humans out of the system (according to technical design rules, e.g., “inherently safe” nuclear reactor designs).

-----  
Insert Figure 2  
-----

---

<sup>3</sup> Industry uses many definitions of root cause such as “the primary or direct cause(s) that, if corrected, will prevent recurrence of performance problems, undesirable trends, or specific incident(s).” In practice, it means a manipulable cause, i.e., a place to intervene to improve performance (Carroll, 1998).

The controlling orientation is supported powerfully by industry and professional norms and cultural assumptions. Both the engineering profession (Rochlin & von Meier, 1994) and the US management profession (Schein, 1996) are trained to plan, analyze complex situations into understandable pieces, avoid uncertainty, and view people as a disruptive influence on technology or strategy. Carroll (1995) argued that the “fixing” orientation is dominated by linear cause and effect thinking, a search among known solutions, a belief in the adequacy of current understanding, and an assumption that “any error is avoidable through engineering design and managerial controls” (p. 187). The “machine” metaphor and technical logic dominates (Carroll, 1998), such that performance is viewed as a summation of component-level, often explicit and measurable, contributions. Technical expertise is honored, and people are organized into workgroups and departments that often become classic “silos” of knowledge.

### The Rethinking Orientation to Learning

As Popper and Lipshitz (1998) suggest, organizational learning involves both a desire to learn and the structures and mechanisms to enact learning effectively. In the nuclear power industry, regulators and industry groups have long been calling for greater awareness of minor problems and actions to avoid future trouble (Jackson, 1996; Rochlin, 1993). As Weick, et al. (1999) state, “to move toward high reliability is to enlarge what people monitor, expect, and fear.” A typical nuclear power plant identifies over 2000 problems or incidents per year, 90% of which would have been ignored a decade ago. Although efforts to accelerate learning may include technological initiatives such as web-based information exchanges and databases of new ideas and best-practice routines (Pan & Scarbrough, 1998; Davenport & Prusak, 1997), the rethinking orientation is based on attitudes and cultural values of involvement, sharing, and mutual respect. Assumptions about authority, expertise, and control give way to recognition of uncertainty (Schulman, 1993) and the need for collaborative learning (see Table 1). There is a climate of psychological safety (Edmondson, 1999) that encourages organization members to ask questions, explore, listen, and learn. Although there is increased monitoring and mindfulness, a *promotion* focus is maintained (Higgins, 1998) that is associated with attention to potential gains, accomplishments, hopes, opportunities, and discoveries.

The rethinking orientation is based not only on a desire to improve and mutual respect among diverse groups, but also on skillful inquiry and facility to gain insights, challenge assumptions, and create comprehensive models (Argyris & Schön, 1996; Senge, 1990). With the stigma of reporting problems minimized, plants are able to surface problems earlier (Carroll et al., in press; Sitkin, 1992). Dialogue among groups with different viewpoints provides feedback about varied assumptions and mental models and the impact of these assumptions on plant outcomes. Double-loop learning skills enable basic assumptions to be questioned (see Figure 1). Participants transcend component-level understanding and additive models of performance to develop more comprehensive and systemic mental models that integrate organizational, cultural, and political viewpoints. Imagination is unleashed to create a wider range of action possibilities and experiments to change deep structures and underlying causes (Miner, 1994; Morris & Moore, 2000).

However, even the best plants struggle with analyzing below the level of equipment problems, human error, and procedure inadequacies (Carroll, 1995, 1998, Carroll et al, 2001). Sophisticated learning practices are not widespread in the nuclear power and chemical industries. Typical investigation practices require analysts to pick from a list of catalogued causes, thus reducing analysis to a search process and forgetting that “the map is not the territory” (Corcoran, 2001). Even when the rhetoric of causality shifts, it may only be the replacement of one simple cause by another. In problem investigation reports, the causes found are those "familiar to the analysts... There is a tendency to see what you expect to find; during one period, technical faults were in focus as causes of accidents, then human errors predominated while in the future focus will probably move up-stream to designers and managers" (Rasmussen & Batstone, 1991, p. 61). Despite a desire to improve, investigators and managers seldom look for fundamental or deep, systemic causes in part because they lack ready-made actions to address such issues and ways of evaluating their success (remnants of the controlling orientation).

Carroll, Serman, & Marcus (1998) relate one example of an innovative technique that introduced new learning practices to Du Pont chemical plants. As part of a company-wide cost-reduction effort, a benchmarking study showed that Du Pont spent more than its competitors on maintenance, yet had worse equipment availability. A reactive culture had developed, with workers regularly pulled off jobs to do corrective maintenance. Responding to the benchmarking study, a series of cost-cutting initiatives were undertaken that had no lasting impact. Finally, one team questioned the basic assumption that reducing maintenance costs could help reduce overall manufacturing costs; they thought that the effects of maintenance activities were tightly linked to so many aspects of plant performance that no one really understood the overall picture.

Du Pont was able to improve maintenance only after a collaborative conceptual breakthrough. An internal team developed a dynamic model of the system of relationships around maintenance (a "modeling for learning" exercise with the assistance of a researcher/consultant, Senge & Serman, 1991). However, they were unable to transmit the systemic lessons of the model through ordinary means. Instead, the team created an experiential game in which plant employees play the roles of functional managers and discover new ways to think about plant activities, share their experiences and ideas, and test how programs and policies can improve performance. Having a broad range of employees with a system-wide understanding of the relationships between operations, maintenance, quality, and costs laid the groundwork for a successful pump maintenance pilot program. With enhanced learning capabilities, the organization had the ability to come up with alternative assumptions and models to guide action toward more desirable outcomes, experiment with the new ideas-in-action, and track feedback on their effectiveness.

In the next section of this paper, we illustrate organizational learning mechanisms in high-hazard industries with case studies and quantitative survey data from multiple investigations. We also consider a case study of an organizational transformation

intended to create a climate of trust such that problems could be reported and more effective actions taken. We draw some lessons about the compelling power of the controlling orientation, but offer hopeful signs that a rethinking orientation is achievable.

## **LEARNING IN ACTION: EMPIRICAL ILLUSTRATIONS**

In the first case study, a nuclear power plant investigated an incident in which an employee was seriously hurt. This plant was attempting to improve safety and performance in part by using a newly upgraded problem investigation process. The investigation created an opportunity to raise collective awareness about local work practices and helped managers strengthen controls and increase conformity to industrial safety rules.

### **Fall From Roof**

An electrical maintenance supervisor sent three men to replace light bulbs inside the “hot” machine shop, the area used to decontaminate equipment of radiological residue. The men headed off to the work area and discussed among themselves how to reach the light bulbs. They decided that one of them, whom we call Joe, would access the lights by climbing on the roof of a shed within the larger building. Joe and one coworker dressed in anti-contamination suits and propped a ladder against the shed wall. Joe crawled up the ladder and onto the roof. As he was about to reach the lights, one of the roof panels gave way, dumping him 10 feet to the ground below. His injuries included several broken bones and a lacerated lung and arm. His coworkers used a nearby phone to call for help. Emergency medical technicians arrived shortly and took Joe to the hospital.

### **The Team Investigation and Managers’ Reactions**

For an event of this seriousness, a multi-discipline team was assembled to collect information, analyze causes, and make recommendations. The team noted that a number of standard operating procedures regarding safety assessment were not followed. When the electrical supervisor assigned three men to the job, no one was designated to be in charge. The supervisor did not conduct a pre-job brief (explaining the operational and safety issues involved in the job) and no one thought to walk down the job (conduct physical examination and discussion of the safety challenges at the work site) or plan the safest way to do the job. The workers failed to follow rules requiring fall protection (e.g., a harness attached to a fixed support) when working aloft and proper use of a folding ladder by unfolding it rather than leaning it against a wall.

The team’s report noted that these actions and omissions may be part of a local culture of risk-taking. The tone of the task was set, in part, by the most senior electrical worker of the three and the only one who had changed these light bulbs before. He told the others that they would “love this job ‘cause it’s kind of tight up there.” Based on their interviews with Joe and others, the investigators speculated that this challenge struck Joe, who had just transferred to this department, as an “opportunity to succeed.” Lastly, the workers ignored warning signs that the job was not routine. Nobody heeded

the implications when Joe was advised to stay on the one and a half-inch steel framework of the building because it was the strongest part. Joe failed to reconsider the job when his hand slipped through a skylight and he nearly fell, shortly before slipping again and falling through.

The investigation team's report documented lack of compliance with established safety practices and suggested ways to enhance compliance with existing rules. The report concluded that:

The cause of the accident was a failure of the employee, the employee in charge, and the supervisor to properly follow the Accident Prevention Manual requirements for working in elevated positions. The hazards associated with the job were not properly assessed; a stepladder was improperly used, and fall protection was not used when climbing on a structure.

The report then recommended that the plant should: 1) raise sensitivity to safety on routine jobs by appointing a full-time safety person; require managers to communicate to supervisors and supervisors communicate to employees the plant's expectations regarding industrial safety; and require department managers to provide feedback to the plant manager on each department's safety issues; 2) make more detailed guidelines on working aloft available to employees; 3) consider instituting a company-wide program on "Working in Elevated Positions," and 4) counsel all employees involved in the incident.

The team's analyses and recommendations had to be negotiated with and implemented by managers. Preliminary reports are typically discussed with management before being formally issued, in order to increase clarity, comprehensiveness, and buy-in. A team member suggested that management had been defensive about initial drafts and the report had "pulled its punches." Another team member reported, "We put together three different drafts and each time someone in upper management disagreed with what we wrote. Finally the plant manager stepped in and accepted our answer." When asked if the team's recommendations had been implemented successfully, a team member responded, "Management took renewed emphasis on safety. Procedures (pre-job briefs) were changed and working aloft programs were implemented." But a different team member replied plaintively, "If top level managers aren't willing to listen to the people doing the work, and respond to their findings, it all becomes a waste!"

#### Discussion: The Compelling Nature of Control

This problem investigation illustrates the plant's effort to strengthen its controlling orientation. The report highlighted the failure of workers and first line supervisor to comply with existing rules and procedures. The corrective actions were aimed at increasing awareness and compliance with these rules by appointing a safety advocate, reinforcing the safety message, and improving procedures. Information was generated about local work practices and compliance with rules that could be shared across groups, discussed openly, and used to institutionalize new work procedures. The focus was on changing actions to comply with rules in order to correct a mismatch

between desired results (keep people safe) and actual results (Joe is hurt), i.e., single-loop learning (Argyris & Schön, 1996).

In a controlling-oriented organization, managers are judged by their lack of problems or the speed with which problems are resolved and control reasserted. Challenges to that control are threatening and become political issues (Carroll, 1995; Tetlock, 1983). The investigation process itself is “delegated participation” (Nutt, 1999), a frequently ineffective process in which representatives suggest solutions to managers who may resist implementation (Carroll et al., in press) for various reasons. Managers avoid expensive actions, or actions without a clear contribution to specific problems in their domain. As one member of the investigation team commented, “When it was becoming apparent what the real problem was [i.e., in management’s domain], I think the group became (temporarily) unsure where to go—what to do—it looked like a big step.”

The investigation team did not question their assumption that “compliance with safety rules will improve safety.” A focus on compliance distinguishes those who make the rules from those who are being controlled. There is a contest for control between managers and engineers who are labeled as strategists and designers of the plant and operators and maintenance people who are labeled as implementers and doers (Carroll, 1998; Schein, 1996). The rules can become an empty ritual as alienated workers withdraw from the learning process. Without the opportunity to challenge underlying assumptions about why they work the way they do and the chance to reshape work accordingly, employees tend to feel that the corrective actions are simply another layer of control imposed from the outside. The investigators did not ask double-loop learning questions such as, “What frames do supervisors and workers hold that let a casual approach to safety develop and endure?”; “How does the status and career advancement system contribute to a culture of risk taking?”; “What frames allowed management to have a design problem (lights in an unsafe place) exist for so long?”; or “How does the work system of separated functions and hierarchical authority inhibit mutual understanding?”

### Quantitative Analysis of Problem Investigation Teams

The Fall From Roof investigation was one of 27 investigations we studied at 3 nuclear power plants (Carroll, Hatakenaka, & Rudolph, 2001). Although two plants were selected for study because of their prior contact with the first author, the third was added because industry experts generally considered it a leader at conducting problem investigations. These investigations addressed the most serious problems and most troubling trends during the previous two years, and were therefore assigned to temporary teams of three or more members from multiple departments who were released from their regular work for the duration of the investigation.

After preliminary interviews at each plant to understand their investigation process and to identify team investigations, lengthy questionnaires were distributed to team members and a shorter version went to managers who identified themselves as sponsors or customers of the reports. The team member questionnaires contained open-

and closed-ended items about the difficulty of the task (complexity of the investigation, the availability of data, time pressure, management support), the team process (directiveness of leadership, encouragement of inquiry and multiple opinions, conflict and resolution style), and outcomes (the quality of the report, the implementation of their recommendations, resultant changes in the plant, and personal learning). There were also measures of cognitive complexity, cognitive style, age, education, work experience, and so forth. The manager questionnaires focused on the difficulty of the task, the quality of the report, its usefulness for creating improvements, and their reasoning about why improvements had or had not occurred. The team reports were also coded for various characteristics loosely grouped into causes, barriers/defenses, learning, corrective actions, and narrative features.

### Team Learning

We assumed initially that team learning would be captured in the official team product, the written report. After all, the report is the artifact that drives the corrective action process and is encoded into work management and problem trending databases. However, we came to understand that the team report is a boundary object (Carlile, in press; Star, 1989) negotiated with managers and therefore represents a subset of that learning (or ignores that learning). We will first discuss the contents of the team reports and the characteristics of the teams and the support they received, and then consider other aspects of what the teams learned.

Our coding of the reports showed a disappointing level of depth and completeness, insight and clarity. The focus was most frequently on single-loop changes to action that involved improving compliance with existing procedures. Consistent with the example of Fall From Roof, teams rarely looked for fundamental or deep, systemic causes. They sometimes did a good job of understanding problems in terms of failed barriers (e.g., design, procedures, supervision) that had actionable responses. Corrective actions could be misaligned with the supposed causes, either leaving causes without corrective actions, or introducing corrective actions without specifying how they would address the causes. Few reports were well-written -- they were sometimes confusing, often redundant, lacking a good story line, and usually in passive voice. There was little evidence of inquiry or proposed actions that could enact double-loop learning and change deep structures (Argyris & Schön, 1996). For example, while some reports identified assumptions and beliefs about work practices that contributed to the problem, the proposed corrective actions almost never addressed these assumptions and beliefs. Controlling for plant, reports with more depth and creativity were associated with larger teams and team members who had more teamwork training, more experience in the nuclear power industry, fewer years in the military, and less Need for Closure<sup>4</sup> (Webster & Kruglanski, 1994). More team diversity was sometimes important, particularly having a greater variety of departments and ages on the team, and the report narrative was enriched by having a variety of cognitive styles (Myers-Briggs Type Indicator, Myers & Myers, 1980).

---

<sup>4</sup> A cognitive style preferring structure and clear answers rather than ambiguity and problems to solve.

Although there were only three plants in our study, one of them was generally considered to be a national leader in problem investigations. The reports we collected from that plant did not exhibit more depth of causal analysis or identification of more generic lessons learned. However, reports did have significantly higher scores on corrective actions matching causes, use of an interdisciplinary approach, and “out-of-the-box thinking” (a composite that reflected an ability to see a problem in terms of past similar problems and potential future problems, cross-context comparisons to other departments and plants, and attention to informal routines). Reports from this plant had better grammatical structure and made better use of graphics. This plant also had significantly larger teams, more departments represented on each team, more managers or supervisors on the teams, and team members with the least years of military service and the lowest scores on Need for Closure. Interviews at the plant consistently discussed how the plant manager strongly supported self-analysis and learning, including requesting involvement of other plants in investigations. This suggests that any advantage of this plant lay not in their analytical and causal models, but rather in their open and cooperative attitude toward learning, their linking of problems across contexts, and their ability to turn analysis into action. These capabilities helped institutionalize a stronger learning orientation.

#### From Team Learning to Organizational Learning

Organizational learning in the form of changes to routines and physical equipment depends upon actions initiated by managers as a result of the problem reports. In general, both team members and managers reported that corrective actions had been implemented and changes had been made that addressed the problems. However, team members frequently reported not knowing what had happened, or that management had been defensive and therefore reports had been less than candid. Teams that reported more change resulting from their reports also indicated that their teams had better relations with management and more training for teamwork. From their side of the negotiation, managers complained about long lists of causes and corrective actions that undermined the impact of the report and seemed to yield little value for the investment. Managers rated change as greater when the team members had more investigation experience and, to a lesser extent, the managers had more trust in the team. In general, the results reinforce the importance of both skills in teamwork and investigation and the external function of teams -- their ability to negotiate resources and goals with management, to obtain information from other groups, and later to “sell” the report (Ancona & Caldwell, 1992; Dougherty & Hardy, 1996; Dutton & Ashford, 1993) from a weak power position analogous to minority influence (Wood et al. 1994).

The challenges of communicating between team members and managers were exemplified by their differing reactions to the team reports. On average, team members and managers thought the teams had “produced excellent reports” (means of 1.80 and 2.12 with 1=strongly agree and 6=strongly disagree), however, these judgments correlated only slightly with each other ( $r=.18$ ,  $n=27$ , n.s.). Teams’ self-ratings of the excellence of their reports were associated with reports that identified failed barriers and generic lessons that could be applied across contexts, self-ratings of good access to

information, sufficient resources, and a good task-oriented team process, and team members whose cognitive styles (Myers-Briggs Type Indicator) were more Judging (conclusion- and action-oriented). Managers' ratings of the excellence of the team reports were associated with reports that suggested effective corrective actions, and came from team members whom the managers trusted and whose cognitive styles were more Sensing-Thinking (logical, practical style typical of US managers, Gardner & Martinko, 1996). Given such differences, we expect much of team learning would remain tacit and unwritten (and possibly be lost) due to time pressure, management embarrassment, or inability to articulate assumptions.

One outstanding counterexample was a report from the well-regarded plant that offered an explicit description of the negotiation process between the team and its management customers. In its initial draft report, the team made over twenty recommendations, which management evaluated and reduced to six, only four of which were implemented. The final report provided a uniquely candid discussion of managers' cost-benefit analyses of all the original recommendations. Reports from this plant were generally more candid than the other plants, perhaps because the plant manager was more supportive of learning. In contrast, at one chemical company we visited, investigation reports were considered a legal requirements to be met in a minimal way that would not expose the plant to additional scrutiny; the important learning was conveyed through oral reports and discussion. Thus, unwritten knowledge was referenced in reports and databases by the names of knowledgeable individuals (cf. transactive memory, Moreland & Mayaskovsky, 2000).

#### Discussion: From Controlling to Rethinking

Given these differences between team members and managers, it is not surprising that plants have difficulty learning from investigations of operating experience. There are different "knowledge reservoirs" (Argote & Ingram, 2000) with different content and different interpretations arising from different mental models or logics (Carroll, 1998). Plants therefore have difficulty putting knowledge into action or implementing anything that managers can not support. In control oriented plants, only a limited number of knowledge reservoirs have sufficient legitimacy to influence management; in more open plants, more knowledge reservoirs are created and used. Interestingly, at a chemical company that we will discuss later, problem investigation activities have the explicit goal of *educating managers*, not solving problems! In this company, teams present facts and tightly reasoned causal connections, but do not make recommendations. It is managers' collective job to understand the problem and its context, discuss improvement opportunities, commission solution development activities, and implement changes.

Organizations that strive for more fundamental change in structure and underlying assumptions and mental models need more participation from a wide range of members (Bartunek 1984). Interestingly, teams from the "industry leader" plant rated diversity of team inputs as significantly more important than did teams from the other plants. Effective learning requires informational diversity (Jehn, et al., 1999) or "conceptual slack" (Schulman, 1993) arising from a mix of occupational and educational backgrounds (Dougherty, 1992; Rochlin & von Meier, 1994) and varied cognitive styles (Jackson,

1992; White, 1984) that together combine abstract, systemic issues with concrete, operational details and technical complexity with human ambiguity. Further, there must be opportunities and skills for engaging in a process of knowing (Cook & Brown, 1999) or double-loop learning that can help surface previously unarticulated mental models of the work environment, compare them, and arrive at new, shared views.

However, the controlling orientation creates barriers against rethinking. For example, in our study of investigation teams, average cognitive complexity of team members emerged several times as a correlate of both internal team activities and external activities, suggesting that more complexity was valued in the team. Yet managers appeared to seek logical and practical solutions to problems, and disparaged complex analyses as attempts to “solve world hunger.” Deeper inquiry that could reveal new insights and systemic understandings requires time to grapple with uncertainty and complexity and therefore that managers permit themselves temporarily to “not know” and “not act” (Schulman, 1993; Weick et al., 1999). Directly involving managers in the investigation activity could be an important strategy, but it is resisted by overworked managers who are encouraged to produce, not learn -- exploit, not explore. As we mentioned earlier, the industry-leading nuclear power plant had more teams with managers or supervisors as team members. The practice of centralizing the investigation process in a specialized staff group can increase the quality of the reports but may also reduce line participation and the indirect benefits of team members returning to their work groups with their new knowledge and extended networks (Gruenfeld et al, 2000).

### Charge Heater Fire

At a petrochemical plant, a plant-wide effort was made to begin using root cause analysis (RCA) teams (their label for problem investigations) as a way to address, simultaneously, a recent history of financial losses, some dangerous incidents, and repeated equipment failures. The idea of using root cause analysis to address adverse incidents in the plant came from a recent merger with another petrochemical company, which used the root cause analysis process already. Two headquarters staff at this petrochemical company had been working for a decade to promote more strategic and systemic thinking at operational and executive levels, using root cause analysis as one of several approaches, and their progress was just beginning to accelerate. The new plant manager had requested that they bring their root cause analysis practice to his plant, beginning with a large-scale learning intervention. The plant decided to train about 20 plant employees, operators, maintenance staff, engineers, and first line supervisors to conduct root cause analyses by dividing them into teams to explore four significant recent problems.

Each problem investigation team included some members from inside and some from outside the plant and at least one experienced root cause facilitator. The overall process included training in investigation, analysis, and reporting methods during the course of a three-week time frame, culminating in reports to plant management. Training was timed to correspond to the needs of the teams as they collected maintenance and operations logs, reviewed physical evidence, interviewed involved parties and knowledgeable experts, analyzed causes, and prepared reports.

One of the investigation teams examined an explosion and fire in a charge heater that cost \$16 Million for lost production and repairs. Charge heaters are large gas-fueled burners used in the transformation of waste products from oil refining back into usable products through hydrocracking, a dirty and dangerous process requiring very high heat and pressure. The residue of this process is coke (coal dust) which can accumulate on the inside of heater tubes. In addition to unearthing the causes of the explosion, plant managers also wanted to discover and ameliorate the conditions that led to this event and might lead to future events.

While the causal analysis presented below may seem extremely straightforward, its simplicity is the result of a rigorous and laborious root cause analysis process that involved four elements: A time line of events; an “Is/Is not” process that differentiates circumstances where the event occurred from similar circumstances where it did not (Kepner & Tregoe, 1981); a detailed causal event diagram; and a process of categorizing the quality of data used to draw inferences in the causal event diagram (as a verifiable fact, an inference, or a guess). In doing these analyses, members of the team argued with each other, built on each other’s ideas, and alternated between stunned amazement and appreciation at the differences in each other’s views of the refinery.

### The Team Investigation

Distilling and analyzing the information available, the team concluded that the explosion and fire were due to a tube rupture inside the charge heater that occurred when the three quarter inch steel skin of the tube got too hot and tore. The team found that three factors contributed to the heater explosion: (1) high heat input, (2) low heat removal, and (3) unawareness on the part of operators of the actual tube skin temperature. First, operators ran the burners in the charge heater unevenly to increase heat and thereby achieve the desired production level, while avoiding alarms that would signal an unsafe condition. Second, heat was removed more slowly than usual from the tube skin because coke had adhered to the inside of the tubes and was acting as an insulator. There was more coke than usual because it was assumed that a new decoking process worked as well as the previous process and no one had checked for coke build up. Third, the combination of running some tubes hotter (at a higher gas pressure) and the build-up of coke moved the maximum heat point up the tube. The thermocouple meant to detect temperature on the tube skin, set at a height specified in the heater design, was now below the hottest part of the tube, so that operators believed the tube temperature was acceptable. The tube ruptured above the thermocouple.

The team noted as a “Key Learning” that plant staff made decisions without questioning assumptions that seemed to underlie them. First, the maintenance department changed decoking processes but did not know and never checked if the new process was effective. Second, operators increased the burner pressure in the charge heater but did not know the consequences of doing so. Third, operators changed the pattern of firing heater tubes (to fire hotter around the perimeter) but again did not know the consequences of doing so. On the basis of these insights, the team’s first

recommendation for future action was that the plant identify “side effects” and be more aware of the broader “decision context” when changing production processes.

The team deepened their analysis as they discussed why assumptions about the effectiveness and safety of the new decoking process and the modified charge heater tube firing practices were never questioned at the time that changes were made. They speculated that their colleagues probably were unaware of the assumptions they were making. Our observations of the team’s investigation and our *post hoc* interviews with team members highlight the team members’ amazement and interest in “how quick we jump to conclusions about things.” The team repeatedly mentioned the fact that, prior to learning the new investigation process, they rarely questioned their own conclusion-drawing processes and the assumptions that underlay them. One team member summarized his new approach by saying he now questions his co-workers: “I say, are you sure? Are you sure? Did you look at the initial aspects of what happened?”

As they worked on the investigation, the charge heater team frequently discussed their discovery of unanticipated and previously unknown interactions between apparently unrelated plant processes such as decoking and tube firing. When the team got to the bottom of their cause tree they noticed that each leg was a necessary but not sufficient contributor to the incident. In one of its verbal reports to other investigation teams during the training sessions, the charge heater team noted that, “We are seeing that several things combine over time to create an event.” Independent decisions by maintenance to change decoking, the inspection service to trust that the new decoking was effective, and operators to change burner tube firing practices, ended up interacting to produce the heater fire. The team described their learning to other teams by saying, “It appears that in most cases there are elements of human factors (systems) that show up if you dig deep enough.”

Based on the insights from this team and from the other teams, the plant decided to implement a “Management of Change Process” to address the unanticipated side effects and interactions that caused problems. According to follow-up interviews with team members six months after their investigation, the actual results are mixed. One team member felt the plant Management of Change process had shown results:

The biggest issue that came out [of the root cause analysis training] was management of change. MOC. Now people pay more attention to adhering to the MOC process. It may be that the RCA training helped focus attention on MOC. MOC is serious. It is real. If you don’t do it, your job is on the line. If you do not do it, you have to explain why not.

However, another team member felt, “There are no legs on the management of change effort. It is just a lot of talk.”

#### Discussion: The Challenges of Rethinking

The charge heater investigation provides examples of an organization striving to motivate openness and learning and also to enhance inquiry and analysis skills. In our observations of the training session, it was evident that at least some participants were

anxious about being open with colleagues in their own department or in other departments, or with management. Would operators talk to engineers? Would an operator working on this investigation be perceived as having sold out? Would managers listen to reports that were critical of their own behavior? The investigation could have blamed the operators for “getting around” the tube temperature alarms, ignored the role of management decisions about production goals, and instituted more monitoring and rules. A punitive response or a controlling approach to learning could have reinforced barriers to the open flow of information and discouraged participation, and failed to get at the underlying, systemic causes of the event.

However, plant management was not approaching its problems from the viewpoint of control. Instead, there was a desire to demonstrate the value of rethinking and deeper learning for achieving better performance. During the course of the training and investigation, teams experienced more openness and collaboration than they expected as managers asked questions, responded to questions from team members, and generally interacted in an open manner. There was a willingness to confront reality and to surface underlying assumptions about “how we do work around here.” Support from the new plant manager helped encourage full participation from the teams and from managers. That support was itself an outcome of the training team who worked publicly with the investigation teams but met *privately* with management to reduce their defensiveness and enlist their visible engagement. And, it was evoked and reinforced by specific features of root cause analysis that require close attention to factual details, data quality, and cause-effect relationships. Yet, employees’ final verdict on management openness would await management action following the investigations.

The team investigation began rethinking when they started addressing operations at the plant from a systemic perspective and challenging assumptions. Team members developed and practiced double-loop learning capabilities. This approach recognizes assumptions and mental models as distinct from reality, understands that assumptions and mental models affect behaviors and outcomes, imagines alternative mental models to guide action toward more desirable outcomes, and takes action with the new mental models (Friedman & Lipshitz, 1992; Argyris, et al., 1985). Paradoxically, the process of “drilling down” precisely and narrowly into causes of this incident allowed the team to develop new awareness of interdependencies across the system. They recognized interactions among components of the system and began to understand a central tenet of the quality movement (e.g. Goldratt & Cox, 1992) that working to optimize individual components does not automatically add up to an optimized system. The process of root cause analysis encouraged awareness of mental models and ability to work *on* mental models rather than *through* them. The rigor of the root cause analysis process encouraged team members to “hold their assumptions lightly” as the analysis held these views up to comparison and disconfirmation. An explicit goal of the investigation and the overall intervention at the plant was to educate management by challenging their mental models with rich and compelling data and interpretations.

For example, the cause-effect diagrams worked as a boundary object to help reveal tacit assumptions about plant processes that were key links in the causal chains

leading to the heater explosion. As team members created these diagrams, they were continually confronted with the fact that each saw the same situation differently, forcing them to recognize that their image of reality was distinct from others' images and from the reality itself. In our interviews with team members, they universally highlighted the benefit of having a diverse team because of the surprising differences among people's ways of looking at the same problem. They discovered how mental models affect behavior when they recognized that three assumptions in their cause-effect tree had contributed to the charge heater fire: "[desired] charge rate [production rate] dictates heater firing"; "sandjetting works as well as steam air decoking [to remove coke from inside heater tubes]"; and "there are no 'hot spots' [overheated areas] on the tubes." Developing a gut sense that assumptions matter in shaping action and outcomes is important to overcome fears about "trying on" new mental models (Rudolph, et al., 2000). Their recommendation that "identifying side effects and documenting decision context become a central part of decision making at [the plant]" implies a new insight: "Decisions made in one context may have side effects in other contexts and these are important to consider."

### The Millstone Turnaround

Moving beyond problem investigations, the final case examines an organization in crisis that had lost the trust of employees and external regulators when managers pushed a classic controlling orientation to the extreme. We step back to examine the organizational conditions that form the context for problem investigations, reflective self-analyses, and learning. Many of the same themes emerge as in the prior studies, but the focus shifts somewhat.

In October 1996, the Millstone nuclear power station outside New London, Connecticut, received an unprecedented order from the US Nuclear Regulatory Commission (NRC) to keep its three plants closed until they could demonstrate a "safety conscious work environment." The problem had come to public attention earlier through a cover story in Time magazine about harassment and intimidation of employees who brought safety concerns to management. An interviewee at Millstone (Carroll & Hatakenaka, 2001) labeled the management culture as "male... militaristic – control and command." A NRC review (Hannon et al., 1996) concluded that there was an unhealthy work environment, which did not tolerate dissenting views and stifled questioning attitudes among employees, and therefore failed to learn and change. As the report said, "Every problem identified during this review had been previously identified to Northeast Utilities management... yet the same problems were allowed to continue."

New senior management was brought in to reestablish the trust of regulators, the public, and employees. Investments were made in physical improvements and extensive documentation to meet rising industry standards, but a critical component was culture change. Employees needed to feel psychologically safe (cf. Edmondson, 1999) about reporting concerns, to believe that managers could be trusted to hear their concerns and to take appropriate action. Managers had to believe that employees were worth listening to and worthy of respect. In short, the underlying values had to change from controlling to

openness and trust. It took over two years to shift the culture and learning orientation of the plant, but in June 1998 the internal oversight groups and external regulators certified that Millstone could restart its largest unit, and a second unit would restart a year later (the smallest and oldest unit was permanently decommissioned) (see Carroll & Hatakenaka, 2001, for more details).

### The Culture Change Journey

In September 1996, the new CEO for Nuclear Power, Bruce Kenyon, set the scene for change with an address to all employees on his first day, in which he introduced his values: high standards, openness and honesty, commitment to do what was right, and two-way communications. He immediately revamped the top management team and introduced a stronger employee concerns program.

His subsequent actions enacted and modeled openness and trust. Throughout the next months, Kenyon met regularly with small work groups and in large all-hands meetings to give information and encourage two-way communication: “It shocked them [employees] to get candid answers.” Upon hearing Kenyon say publicly at his first NRC meeting that he found the organizations “essentially dysfunctional,” an interviewee from the NRC remembers thinking, “here’s a fellow who at least recognizes the problem.” Based on recommendations from an employee task force redesigning the Employee Concerns Program, Kenyon agreed to create an Employee Concerns Oversight Panel (ECOP) to have an independent voice and report directly to him. ECOP was staffed with passionate advocates who argued with each other and with management, but over time they evolved a workable role. The panel’s existence “sent a message to the work force that employees could act as oversight of management.”

Kenyon allowed himself to be fallible and to enlist participation. When two contractors were terminated for alleged poor performance and the Director of the Employee Concerns Program provided evidence that the terminations had been improper, Kenyon quickly reversed his decision. As one of his senior managers recalls about their working relationship, Kenyon “went along with all my recommendations. He didn’t always agree... [Sometimes he] swallowed hard.” He called upon employees to voice their public support for Millstone to counterbalance media criticism: “when are you going to say what you think?” In response, an ad hoc employee group self-organized, gathered over 1500 signatures on a petition, attended public meetings, wrote to newspapers, and otherwise expressed their commitment to a management that trusted them to become part of the solution.

Individual managers told stories of personal transformations and how they came to understand the nature of the problems. The case of the operations vice president was perhaps the most dramatic. Typical of the old-style management, he was weary of “whiners,” and “didn’t believe anyone would harass someone who brought forth safety concerns.” When the two contractors were terminated and the employee concerns program offered their view that the terminations were improper, “It was one of those moments your perception changes... a watershed for me.” He also remembers vividly his visit with several other Millstone managers to another nuclear power plant that had made

a dramatic turnaround, where he learned that attention to safety concerns could make business sense.

Millstone was typical of an industry in which managers are “not high on people skills, for example, few can read nonverbal signals.” They had to appreciate that employees’ perception was their reality. For example, when members of the training and operations departments were disciplined for inaccuracies in training documentation two years earlier, employees immediately assumed that the former training director was being punished because he had been an outspoken critic of management. Management had failed to anticipate reactions or to minimize the impression of retaliation. Managers had to learn new skills, including sensitivity to their own and others’ emotions and perceptions. Through extensive new training programs and coaching by organizational development consultants, they had to “learn the difference between anger, hurt, and a chilling effect” and avoid confusing a fear of reprisal with a lack of confidence that management would take effective action.

Openness and trust emerged organically through multiple mechanisms and venues. We have already mentioned the Employee Concerns Program (ECP) that provided confidential ways to report issues for investigation and the Employee Concerns Oversight Panel (ECOP) that connected employee representatives directly to the CEO Nuclear. The Executive Review Board was created after the contractor terminations to review all disciplinary actions, comprising senior managers and an ECOP representative as an observer. By opening up the management process, it helped restore employee trust in management, and created an environment for managers to learn and enact new values. The People Team, a coordinating group among human resources, legal department, ECP, ECOP, management, and organizational development consultants, met daily to respond to problems and organize to address issues and monitor progress. Internal Oversight groups and an independent third-party consulting group required by the NRC provided additional monitoring and advice. These multiple mechanisms and forums allowed broad participation so that managers and employees could share information, develop common language, learn by doing, and build trust by reacting well to challenges.

Discussion: Improvisation and Emergent Change

The NRC requirement that Millstone develop a “safety conscious work environment” and demonstrate this to the satisfaction of an independent third-party consultant was unprecedented in the industry. The NRC offered no guidance. Millstone had to find its own way to move from a regime of centralized authority and mutual distrust to a culture of open communication, trust, and participation.

Millstone managers were proud of Millstone’s excellent record in the industry, built on technical leadership of the industry. Managers believed that Millstone’s design features and managerial controls were sufficient to operate the plant safely and reliably. When employees complained about technical problems or the external regulators criticized them for lack of documentation or growing backlogs of work, managers ignored them or blamed the messengers. Management’s basic assumption was, “we know everything we need to know.” Meanwhile, employees developed a basic

assumption that “management can’t be trusted.” In short, managers and employees (and regulators and publics) lived in separate thought worlds (Dougherty, 1992) with strong cultural barriers and a perceived contest for control.

New senior management, external intervention, and an infusion of outside employees broke through some of that defensiveness. Because senior management reacted well to critical events such as the contractor terminations and independent voices were allowed to challenge underlying assumptions, double-loop learning occurred. Multiple venues emerged for managers and employees to talk together and work on the common problem of rebuilding Millstone. Managers began to listen and trust the employees enough to act on what was being said; in turn, employees began to feel safer about speaking out (Edmondson, 1999) and to trust that management would listen and take action. The most powerful way to regain trust is to work together with a common purpose (Kramer, 1999; Whitener, Brodt, Korsgaard, & Werner, 1998).

Managers not only became more open to information coming from employees and external observers, but also became aware of new kinds of information. The more open environment at Millstone marked an increase in interpersonal skills and emotional intelligence (Goleman, 1995). Controlling-oriented managers, some of whom get their way by yelling and threatening, are generally unaware of their own emotionality and try to restrict any emotionality in their subordinates. They claim to value facts and rationality, even when they are using fear to exercise control. Managers had to learn that emotions and perceptions are reality. Emotions and perceptions can be anticipated, considered, discussed, and managed.

### **A STAGE MODEL OF ORGANIZATIONAL LEARNING**

Research specifically on organizational learning and more generally on organizational growth and development suggests a progression in structure, goals, skills, and culture. Whether we use a biological metaphor to talk about individual growth and learning (e.g., Rooke & Torbert, 1998), organizational life-cycles (e.g., Quinn & Cameron, 1983), or an historical analysis of organizational forms over time (Chandler, 1962; Malone & Smith, 1988; Perrow, 1970), we repeatedly find a progression in size, complexity, and interdependence with a more intrusive and unpredictable environment. Bohn (1994) provides a stage model of increasing process control knowledge, and Reason (1997, pp. 61-65) offers a stage model of organizational control that moves from predominantly feedforward embedding of anticipated problems into procedures to predominantly feedback learning from experience.

The four stages in Figure 2 are presented as a provocative guide to analysis, not as a rigid model of development. “As Weber noted, ideal types are useful not because they are descriptively accurate – actual instances rarely evince all of the attributes of an ideal type – but because they serve as models that assist in thinking about social phenomena” (Barley & Kunda, 2001, p. 83). In any organization, there will be examples of each stage in operation in different parts of the organization and at different moments in time. It is healthy for organizations to enact multiple learning orientations and processes at many organizational levels (individual, team, department, and so forth) in order to draw

on a wide range of capabilities and enable a creative tension between different approaches (Crosson & Hurst, 2001; Crosson et al., 1999; Weick et al., 1999). However, the latter stages require shared understanding and collaborative effort across the organization, so these capabilities must become relatively widespread and commonly enacted if they are to be sustained. Although we propose that these stages and capabilities tend to emerge in a particular order, being “at” a stage means that there is relatively more behavior consistent with that stage and *earlier* stages.

-----  
Insert Figure 2  
-----

### Local Learning Stage

Most organizations begin their lives small, relatively unstructured, and personal or informal, like an entrepreneurial startup (Quinn & Cameron, 1983) or a craft shop (Perrow, 1970). Despite the focus of research on large corporations, the vast majority of firms employ under 100 workers (Aldrich, 1999). Of course, early nuclear power plants were more proceduralized than small craft shops, but they were more like fossil fuel plants in drawing knowledge from the experiences and skills of individuals. In such an early stage, organization-specific and task-specific knowledge is local, contextual (Carlile, in press), tacit (Nonaka & Takeuchi, 1995), and sticky or hard to transfer (von Hippel, 1994). Exceptions occur frequently, and the organization relies on technical expertise to cope with surprises and provide flexibility or resilience (Wildavsky, 1988). Decisions are made locally by those steeped in the details, and learning mostly occurs locally as well. Learning is decentralized in individuals or workgroups and primarily single-loop, i.e., behaviors are adjusted after comparison to performance standards or benchmark models, but underlying structures and assumptions are not challenged (see Figure 1). The organization is minimal and hardly self-aware.

For example, from the beginning of the nuclear power industry, design engineers appear to have understood plant construction as a finite project that results in a production machine. Once built and debugged, the plants were expected simply to run, a belief echoed by nuclear utilities and regulators: "Technological enthusiasts heading the AEC [Atomic Energy Commission] believed most accidents were too unlikely to worry about" (Jasper, 1990, p. 52). Given this belief, little attention was paid to “minor” problems in a plant or other plants in the industry, unless those problems affected production. When a combination of minor problems and operators doing what they were trained to do produced the Three Mile Island (TMI) event in 1979, this constituted a "fundamental surprise" (Lanir, 1986) for the nuclear power industry. The information needed to prevent the TMI event had been available from similar prior incidents at other plants, recurrent problems with the same equipment at TMI, and engineers’ critiques that operators had been taught to do the wrong thing in particular circumstances, yet nothing had been done to incorporate this information into operating practices (Marcus, Bromiley, & Nichols, 1989). In reflecting on TMI, the utility’s president Herman Dieckamp said,

To me that is probably one of the most significant learnings of the whole accident [TMI] the degree to which the inadequacies of that experience

feedback loop... significantly contributed to making us and the plant vulnerable to this accident” (Kemeny, et al., 1979, p. 192).

In the local stage, information necessary for learning does not travel easily beyond particular workgroups and contexts. The Fall From Roof and Charge Heater Fire cases offer examples of work practices among maintenance workers, operators, and engineers that were learned over time because they appeared effective and efficient to the work groups involved. In the case of Fall From Roof, industrial safety was being compromised in a way that primarily affected the workers themselves, but secondarily reflected a generally casual attitude toward rules. A major lesson from the Charge Heater Fire investigation was that local groups were making changes in routines that appeared more effective from their viewpoint, but they never checked with other groups about the impact of those changes on the plant as a whole system. Their local practices only came to light when implicated in a serious event, and even then only when investigators were able to gather rich information and analyze it with a highly-disciplined set of conceptual tools.

### Constrained Learning Stage

The constrained stage was described extensively in our earlier discussion of the controlling orientation. By “constrained” we mean limited by assumptions, mental models, habitual routines, and entrenched interests seeking to preserve their status and perceived competence (cf. constrained action, Crosson & Hurst, 2001; Pfeffer, 1982). Constrained learning includes a familiar and coherent set of assumptions about expertise, linear cause and effect, and formalization (see Table 1). In the nuclear power industry, for example, the decade after Three Mile Island was characterized by dramatic increases in regulations, formal procedures, internal and external oversight, reporting requirements, and staffing. The industry developed sophisticated probabilistic techniques for anticipating problems (US Nuclear Regulatory Commission, 1975) and industry organizations (e.g., Institute of Nuclear Power Operators, see Rees, 1993) to promote training and exchanges of information and best practices. In our data from the nuclear power industry problem investigation teams, most were working to establish and maintain control over local work processes and to prevent future problems. As we noted, their analyses rarely went very deep into underlying processes and assumptions, but rather executed single-loop learning in an efficient and thorough manner to fix problems. Similarly, when best practices are transferred without rethinking assumptions about why they work, the best practices are being used for fixing or exploiting what is known rather than challenging mental models and exploring new possibilities.

Controlling through measurement, monitoring, incentives, and other traditional bureaucratic mechanisms seems to come naturally to managers and engineers (Carroll, 1998; Schein, 1996). Supported by cognitive biases such as the fundamental attribution error (Nisbett & Ross, 1980) and the illusion of control (Langer, 1975), this orientation may be universal, or at least deeply embedded in Western industrialized culture. In the stable and protected environment of a regulated industry with a relatively fixed technology base and public pressure for reliable and safe performance, a controlling

orientation and skilled use of single-loop learning may be appropriate (cf. Miner & Mezias, 1996).

However, the constrained learning stage can become a competency trap (Levitt & March, 1988). The Millstone case starts from a controlling orientation pushed so far that information contrary to strongly held assumptions was resisted by authority, and learning was inhibited. As the nuclear power industry deregulates and downsizes, new ways of organizing will be needed. Will the industry react with more controlling moves that may further constrain learning, or find ways to juxtapose controlling with rethinking? While adopting programs such as TQM or “learning organization” may be useful, anecdotal evidence from our interviews suggests that companies adopt these programs more to copy success stories and achieve legitimacy rather than through commitment and understanding. No wonder so many companies rapidly move on to the next management fad. As we pointed out in the Charge Heater Fire case, it is the concepts underlying the tools, not simply the tools themselves, that separate a rethinking approach from a controlling approach.

### Open Learning Stage

Large, conservative, bureaucratic organizations can be highly successful in stable environments, but as we observed in the preceding section, in turbulent and unpredictable environments, they may be stuck in a competency trap that inhibits learning. Bureaucratic controls over behavior fail when routines cannot be written and rewritten for all activities and when learning is restricted to specialized groups such as R&D. For example, Perron & Friedlander (1996) suggest that management systems for Process Safety Management in the chemical industry “cannot yet be fully automated” (but notice the “yet”). Facing pressures from new competitors with new products, rapidly-changing technologies and customer preferences, deregulation, and so forth, large organizations may initially ignore these threats (Freeman, 1999). Eventually, increased pressure and enlightened employees at various levels may open the organization to self-analysis, elaboration of bureaucratic mechanisms, and more innovation (Quinn & Cameron, 1993). Benchmarking, for example, can open up learning opportunities by offering comparisons to more kinds of organizations and focusing attention on multiple ways to enhance performance rather than blindly copying the practices of industry leaders.

Most of the organizations we have studied seem to move out of the constrained stage by first recognizing the limitations of top-down control and promoting more participation and open exchange of information throughout the organization and between the organization and the outside world. For example, the industry-leading nuclear power plant in the questionnaire study had an open learning environment supported by the plant manager. The “questioning attitude” and “safety culture” advocated in these industries are directed at acknowledging doubt (Schulman, 1993), increasing awareness or mindfulness (Weick et al., 1999), respecting the contributions of others in an atmosphere of trust (Edmondson, 1999), and placing a positive value on teamwork and learning. Such trust can only be developed by observations of the experience of courageous pioneers (including whistleblowers) who take early risks to tell the truth. When others

validate open behavior, as occurred over time in the Millstone case, trust is built and openness spreads in a virtuous cycle.

The open stage at Millstone was also characterized by an awareness of people as different from machines. An ability to acknowledge emotions, conflicts, and different perceptions that underlie work relationships and political contests allows for discussion of the human side of organization. This double-loop learning challenges deep assumptions about human nature and the role of people in technological organizations (cf. Schein, 1992). Of course, many Millstone managers were uncomfortable and initially incompetent in this domain, but openness to its importance allowed a variety of mechanisms to emerge that institutionalized a new set of assumptions, new organizational practices, and a higher level of people skills. Over time, managers and employees learned by doing and through feedback from colleagues and coaches.

However, it is difficult to sustain an organization at the open stage unless people develop significant skills at producing usable knowledge that improves performance and maintains legitimacy for learning. Individuals and groups may be able to maintain openness as a desired value, especially with the support of senior management. But without demonstrable results, the open stage is vulnerable to forces that resist change (Schein, 1992) and push the organization to return to the familiarity and predictability of the constrained stage.

### Deep Learning Stage

Openness to learning becomes linked to a discipline for learning in the deep learning stage. The complexity and pace of change of modern organizations requires more than a desire to learn. Special circumstances for learning and concepts and techniques that make learning more efficient are needed to break through long-held assumptions and cognitive habits. Deep learning is not simply the use of particular techniques such as root cause analysis. There are many versions of “root cause analysis,” most of which are used with minimal training to find and fix problems (Carroll, 1995) rather than to challenge deep assumptions with rigorous and systemic thinking, just as TQM can be used for controlling rather than learning (Sitkin et al., 1994). As illustrated in the Charge Heater Fire investigation, it is not the use of particular tools such as root cause analysis that leads to learning. Actions and assumptions must be rethought in the context of new *concepts* that underlie the tools, such as data quality, rigorous cause-effect connections, systems thinking, mutual respect across groups, insight into personal and political relationships, and double-loop learning. The tools and the learning activities are only an opportunity to have new conversations, enact new behaviors, develop new skills, and build new relationships.

A major assumption underlying the intervention at the petrochemical plant is that managers do not control people; managers establish the conditions for performance, i.e., they manage the system by providing the resources (people, time, money, equipment, plans, opportunities, legitimacy, procedures, etc.) by which the system will operate. A good system may be difficult to understand; its principles may be hard to verbalize yet

possible to learn through action or instruction. Consider the analogy of newcomers to rowing who typically maintain a rigid grip on their rowing oar because it gives them the *feeling* of control. However, a rigid grip decreases absorption of the shock of uneven waters, thereby decreasing *actual* control. Managers who use “heavy-handed” incentives and authoritative micromanaging may drive noncompliance out of sight and increase their feeling of control, but they may simultaneously increase hidden noncompliance (cf., Reason, 1997) and make the system more difficult to manage.

Experience with deep learning cycles increases tolerance for short-term difficulties and resource shifts away from production toward learning. A systemic view (e.g., Senge, 1990; Senge & Sterman, 1991) suggests that changes take time to unfold and that things get worse before they get better (since resources are shifted away from immediate needs). Problems are not simply someone’s fault, but rather a feature of the system. In a system, there are no “root causes” or “first causes” since causes are also effects. However, this does not leave individuals powerless or remove responsibility (as control-oriented managers fear). A deeper understanding of the system reveals leverage points, suggests new interventions, and allows a richer conversation about the implications of interventions. Selective investment can produce more than ceremonial changes; practice can be transformed.

### **A FRAMEWORK FOR ORGANIZATIONAL LEARNING STAGES**

The four organizational learning stages can be thought of as a progression, but the stages can also be examined for underlying dimensions and symmetries. In Figure 3, we organize the four stages into a 2 X 2 table representing two dimensions: (1) single- and double-loop learning and (2) improvising and structuring. As we have discussed earlier in this paper, single-loop learning adjusts goal-oriented actions based on feedback to better achieve the same goal (Argyris, et al., 1985). In double-loop learning, a deeper inquiry surfaces and challenges underlying assumptions and values regarding the selection of that goal (see Figure 1). Improvising is a process of acting intuitively into an emerging situation rather than following structured procedures or plans (Weick, 1998). In relation to the organizational learning framework of Crossan et al (1999), improvising draws on processes of imagining and, to a lesser degree, interpreting and integrating. Structuring is about consistency and predictability embodied in routines and shared mental models. In relation to Crossan et al (1999), structuring draws on processes of institutionalizing and, secondarily, integrating and interpreting.

-----  
Insert Figure 3  
-----

The above analysis offers two important insights. First, it emphasizes the importance of the two dimensions. Although Table 1 offers many differences between the controlling and rethinking orientations, the clearest underlying distinctions among the four stages seem to be the capabilities for single- and double-loop learning, improvising, and structuring. Second, progress through the stages zigzags through the dimensions. In

particular, the transition from constrained to open involves changing *both* dimensions, moving from structured single-loop learning to improvised double-loop learning. Perhaps this is another reason why the transition is so difficult and organizations adhere so strongly to the constrained stage. Our third insight is more controversial – there will undoubtedly be arguments about whether the fourth stage should emphasize more rather than less improvisation. We came to our conclusions from a small number of case studies and a modicum of speculative analysis. However, we reiterate that organizations at the fourth stage have come through the earlier stages and are exhibiting behaviors and capabilities from the earlier stages. Thus, the deep learning stage *adds* structured, disciplined learning capabilities onto the learning values and improvisational capabilities of the open stage (as well as the capabilities of the local and constrained stages).

## DISCUSSION AND CONCLUSIONS

### Stages of Learning

In summary, we have argued for the importance and difficulty of learning from experience. Nuclear power plants and chemical plants are challenged by the hazards in their work processes to learn from problems and to overcome barriers to learning. The history of these industries and the case studies we have examined suggest that there is a common progression from local learning to a control orientation associated with single-loop learning, which is then held in place by managerial and professional culture. Yet problems continue to occur and many organizations seek to be more proactive by becoming learning organizations that incorporate mutually-reinforcing elements of attitudes and thinking patterns. Our results suggest that, to some degree at least, attitudes favorable to learning precede double-loop learning skills. The concepts and skills of deep learning seem to be difficult to master and to require significant commitment, discipline, and learning-in-action. Of course, the idea of stages is an oversimplification, and it is not necessarily the case that learning in earlier stages is always simpler or easier than in later stages. For example, some cultural assumptions may be quite easy to surface and challenge and some technical problems may be quite difficult to fix.

In portraying the stages as both a linear sequence and a 2X2 table, we revisit the question of whether these are “stages” that occur in a fixed sequence or something more like capabilities that are distributed in a complex and dynamic way across location and time. While issuing the obligatory call for further research, we also maintain that both frameworks are valid. Organizations exhibit all the capabilities we have discussed, in various mixtures and degrees, but some capabilities are more difficult to develop and sustain, and therefore tend to flower later. We believe that local learning (which relies heavily on single-loop and improvisational processes) is a natural starting place. It seems cognitively and culturally easier to move toward structure than to move toward double-loop learning; hence, the control stage tends to come next. Only later will organizations develop broad capabilities to challenge assumptions and explore the unpredictable. Initially, we believe that the motivation to be open typically precedes skills at deep learning, and our case studies support that sequence.

By separating out the stages, the attributes that distinguish them, and the capabilities they include, we have articulated processes involved in organizational learning and the development of absorptive capacity (Cohen & Levinthal, 1990). We have also demonstrated relationships between team, organizational, and individual levels of learning and between cognitive, affective, and behavioral aspects of learning.

#### Levels of Learning: Team, Organizational, and Individual

A consistent theme underlying the empirical examples was the importance of boundary spanning or bridging activities (Ancona & Caldwell, 1992; Cook & Brown, 1999; Yan & Louis, 1999). Our study of problem investigation teams showed that access to information was a critical component of success from the teams' viewpoint. The teams themselves were opportunities to bring together diverse individuals from multiple organizational groups. This was particularly valued in the teams from the industry-leading plant. In the petrochemical plant, teams were composed not only of diverse internal members, but also included participants from outside the plant. The cause-effect diagrams were boundary objects (Carlile, in press; Star, 1989) negotiated by the team in a process of knowing (Cook & Brown, 1999) that helped surface previously unarticulated mental models of the work environment, compare them, and arrive at new, shared views. Some of the learning was articulated in the written report, another boundary object negotiated between the team and managers that initiated corrective actions and fed databases, but much remained unwritten (although discussed as part of the reporting out process). New conversations emerging from the learning process cut across levels of hierarchy and areas of expertise. These conversations built mutual respect and trust in emerging communities of practice (Brown & Duguid, 1991) with new vocabularies and new ways of thinking and acting.

Team learning became organizational learning in several ways. The team report became a record of some of that learning, and the report and the conversations around the report drove change processes that embedded learning in the organization. Involvement of a wider range of employees from various groups helps connect key decision makers to the process. Team members brought learning back to their groups. In short, "learning occurs at several different but interrelated levels at the same time" (Levinthal & March, 1993, p. 100). Our empirical examples illustrate the importance of involving management in these activities. Managers reacted more favorably to reports from team members they trusted for their expertise and judgment. Direct management involvement on the teams, which was more likely at the industry-leading plant, was associated with more trust of the teams. The US Army After Action Review process, for example, has senior officers take the facilitator role in discussions of problems and successes in the recent action (Garvin, 2000). The conditions necessary for this to be successful rather than to arouse defensiveness on the part of subordinates (cf. Millstone) were outlined in our discussion of the open stage, but they include the demeanor of the officers and the strict separation of information in this process from the personnel evaluation process.

We must not ignore that individuals at any level can have impact on organizational learning. It may be more common for a plant manager or CEO to bring

new values and set new conditions, as occurred at the industry-leading plant and at Millstone. However, other individuals contributed creative new ideas that were institutionalized at Millstone, such as the Executive Review Board, the People Team, and the formalized response structure. The Director of the Employee Concerns Program protested and ultimately overturned the CEO's decision on contractor firing, a critical event for culture change at Millstone. From positions of little formal authority, two headquarters staff at the chemical company had been working for a decade to promote more strategic and systemic thinking at operational and executive levels, using root cause analysis as one of several approaches. Only in the past two years have they received significant management support and institutionalization of new practices at several plants.

Levels of learning extend beyond the organization as well. The nuclear power industry has built extensive capabilities for exchanges across plants and industry-wide learning. More opportunities exist for learning across industry, including conferences, workshops, and consultants who bridge industries. For this reason, the fourth organizational stage of deep learning is not an ending point, since the organization itself can be thought of as *local* within industry, value chain, professional, and national boundaries that can be bridged with new learning capabilities. This reinforces the argument of Crosson and Hurst (2001) that organizations cycle between exploration and exploitation to emphasize that developmental cycles of integration and renewal also cut across levels.

### Action, Cognition, and Emotion in Organizational Learning

This paper has focused on a particular set of learning mechanisms, primarily the off-line reflective practices around problem investigation teams. These off-line reflective practices engage two levels of learning-in-action. On one level, problem investigation teams address the "off-line" subject matter of their official task -- the problem and its causes and solutions -- in order to help the organization learn about its performance. But at the personal and team level, they are engaged "on line" in an activity that can challenge their assumptions about how people and organizations learn and change. Team members learn about themselves and each other, develop networks of relationships, and build skills at inquiry, analysis, and imagination. Such knowledge has to be constructed by users, individually and collectively improvised, tried out and modified to suit the occasion.

Beyond the interplay of action and reflection, however, is the engagement of *emotions*. Anxiety and fear are impediments to learning and change, whereas a desire to learn (prompted by intrinsic interest or external threats) and trust and support from others engages learning and imagination (Amabile, 1996; Edmondson, 1999; Schein, 1992). The difficult transition from the constrained stage to the open stage, in particular, engages new learning skills and new attitudes. Double-loop learning potentially undermines the skill and expertise of those who have helped the organization fix its problems and strengthen controls. Courting ambiguity and loosening structure can provoke anxiety. Powerful stakeholders may be threatened if their assumptions and their status are

challenged. Openness may create conflict as individuals and groups with minority viewpoints exercise their commitment to the organization or their desire to increase their own status. Thus, we are beginning to see that organizational learning requires connections among action, reflection, and emotion, in *energizing* knowledgeable action (implementation) and actionable knowledge (sensemaking) (Argyris, et al, 1985; Crossan, et al., 1999; Weick et al., 1999). Future research will undoubtedly put more flesh on the bones of these ideas, and contribute alternative ways to think about organizational learning.

## REFERENCES

- Amabile, T. M. (1996). *Creativity in context*. Boulder, CO: Westview.
- Aldrich, H. (1999). *Organizations evolving*. Thousand Oaks, CA: Sage.
- Ancona, D. G. & Caldwell, D. F. (1992). Bridging the boundary: External activity and performance in organizational teams. *Administrative Science Quarterly*, 37, 634-55.
- Argote, L. (1999). *Organizational learning: Creating, retaining and transferring knowledge*. Norwell, MA: Kluwer.
- Argote, L. & Ingram, P. (2000). Knowledge transfer: A basis for competitive advantage in firms. *Organizational Behavior and Human Decision Processes*, 82, 150-69.
- Argyris, C. (1996). Unrecognized defenses of scholars: Impact on theory and research. *Organization Science*, 7, 79-87.
- Argyris, C., Putnam, R., & Smith, D. M. (1985). *Action science: Concepts, methods and skills for research and intervention*. San Francisco: Jossey-Bass.
- Argyris, C. & Schön, D. (1996). *Organizational learning II: Theory, method, and practice*. Reading MA: Addison-Wesley.
- Bandura, A. & Walters, R. H. (1963). *Social learning and personality development*. New York: Holt.
- Barley, S. R. & Kunda, G. (2001). Bringing work back in. *Organization Science*, 12, 76-95.
- Baron, J. & Hershey, J. (1988). Outcome bias in decision evaluation. *Journal of Personality and Social Psychology*, 54(4), 569-79.
- Bartunek, J. M. (1984) Changing interpretive schemes and organizational restructuring: The example of a religious order. *Administrative Science Quarterly*, 29, 355-372.
- Berlyne, D. E. (1960). *Conflict, arousal and curiosity*. New York: McGraw-Hill.
- Bohn, R. E. (1994). Measuring and managing technological knowledge. *Sloan Management Review*, Fall, 61-73.
- Bourrier, M. (1999). Constructing organizational reliability: The problem of embeddedness and duality. In J. Misumi, B. Wilpert, & R. Miller (Eds.), *Nuclear safety: A human factors perspective*. Philadelphia: Taylor & Francis.
- Brown, J. S. & Duguid, P. (1991). Organizational learning and communities-of-practice: Toward a unified view of working, learning, and innovation. *Organization Science*, 2, 40-57.
- Campbell, D. T. (1969). Variation and selective retention in social-cultural evolution. *General Systems*, 14, 69-85.
- Carlile, P. R. (in press). A pragmatic view of knowledge and boundaries: Boundary objects in new product development. *Organization Science*.
- Carroll, J. S. (1995). Incident reviews in high-hazard industries: Sensemaking and learning under ambiguity and accountability. *Industrial and Environmental Crisis Quarterly*, 9, 175-197.
- Carroll, J. S. (1998). Organizational learning activities in high-hazard industries: The logics underlying self-analysis. *Journal of Management Studies*, 35, 699-717.
- Carroll, J. S. & Hatakenaka, S. (2001). Driving organizational change in the midst of crisis. *MIT Sloan Management Review*, 42, 70-9.

- Carroll, J. S., Hatakenaka, S., & Rudolph, J. W. (2001). Problem Investigation Teams in High-Hazard Industries: Creating and Negotiating Knowledge for Organizational Improvement. *Management Science*, under review.
- Carroll, J. S., Rudolph, J. W., Hatakenaka, S., & Boldrini, M. (in press). The Difficult Handoff from Incident Investigation to Implementation. Paper presented at the New Technologies and Work Conference, Bad Homburg, Germany, May, 1999. To be a book chapter in an edited book from the conference contributions.
- Carroll, J. S., Sterman, J., & Marcus, A. A. (1988). Losing the Maintenance Game: How Mental Models Drive Organizational Decisions. In R. N. Stern & J. J. Halpern (Eds) *Debating rationality: Nonrational aspects of organizational decision making*. Ithaca, NY: Cornell University ILR Press.
- Chandler, A. D. (1962). *Strategy and structure*. New York: Doubleday.
- Cohen, W. M. & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly*, 35, 128-152.
- Cook, S. D. N. & Brown, J. S. (1999). Bridging epistemologies: The generative dance between organizational knowledge and organizational knowing. *Organization Science*, 10, 381-400.
- Corcoran, W. (2001). Personal communication, August.
- Crossan, M. M. & Hurst, D. (2001). *Strategic renewal as improvisation: Reconciling the tension between exploration and exploitation*. London, Ontario: Richard Ivey School of Business, unpub. ms.
- Crossan, M. M., Lane, H. W., & White, R. E. (1999). An organizational learning framework: From intuition to institution. *Academy of Management Review*, 24, 522-37.
- Crossan, M. M., Lane, H. W., White, R. E., & Djurfeldt, L. (1995). Organizational learning: Dimensions for a theory. *International Journal of Organizational Analysis*, 3, 337-60.
- Daft, R. L. & Weick, K. E. (1984). Toward a model of organizations as interpretation systems. *Academy of Management Review*, 9, 284-295.
- Davenport, T. & Prusak, L. (1997). *Working knowledge*. Boston, Harvard Business School Press.
- Davoudian, K., Wu, J., & Apostolakis, G. (1994). Incorporating organizational factors into risk assessment through the analysis of work processes. *Reliability Engineering and System Safety*, 45, 85-105.
- Dougherty, D. (1992). Interpretive barriers to successful product innovation in large firms. *Organization Science*, 3, 179-202.
- Dougherty, D. & Hardy, C. (1996). Sustained product innovation in large, mature organizations: Overcoming innovation-to-organization problems. *Academy of Management Journal*, 39, 1120-53.
- Edmondson, A. (1999). Psychological safety and learning behavior in work teams. *Administrative Science Quarterly*, 44, 350-383.
- Fiol, C. M. & Lyles, M. A. (1985). Organizational learning. *Academy of Management Review*, 10, 803-813.
- Freeman, S. F. (1999). Identity maintenance and adaptation: A multilevel analysis of response to loss. *Research in Organizational Behavior*, 21, 247-294.

- Freidman, V. J. & Lipshitz, R. (1992). Teaching people to shift cognitive gears: Overcoming resistance on the road to Model II. *Journal of Applied Behavioral Science*, 28(1), 118-136.
- Frisch, D. & Baron, J. (1988). Ambiguity and rationality. *Journal of Behavioral Decision Making*, 1, 149-57.
- Gardner, W. L. & Martinko, M. J. (1996). Using the Myers-Briggs Type Indicator to study managers: A literature review and research agenda. *Journal of Management*, 22, 45-83.
- Garvin, D. A. (2000). *Learning in action: A guide to putting the learning organization to work*. Boston, MA: Harvard Business School.
- Glynn, M. A., Lant, T. K., & Milliken, F. J. (1994). Mapping learning processes in organizations: A multi-level framework linking learning and organizing. *Advances in Managerial Cognition and Organizational Information Processing*, Vol. 5. Greenwich, CT: JAI Press, pp. 43-83.
- Goldratt, E. M. & Cox, J. (1992). *The goal: A process of ongoing improvement*. Great Barrington, MA: North River Press.
- Goleman, D. (1995). *Emotional intelligence*. New York: Bantam.
- Gruenfeld, D. H., Martorana, P. V., & Fan E. T. (2000). What do groups learn from their worldiest members? Direct and indirect influence in dynamic teams. *Organizational Behavior and Human Decision Processes*, 82, 45-59.
- Hannon, J. N. et al. (1996). *Millstone Independent Review Group, Handling of Employee Concerns and Allegations at Millstone Nuclear Power Station Units 1, 2, & 3 from 1985 - Present*. October 24.
- Higgins, E. T. (1998). Promotion and prevention: Regulatory focus as a motivational principle. *Advances in Experimental Social Psychology*, 30, 1-46.
- Huber, G. P. (1991). Organizational learning: The contributing processes and the literatures. *Organization Science*, 2, 88-115.
- Isaacs, W. (1999). *Dialogue and the art of thinking together*. New York, NY: Currency Doubleday.
- Jackson, S. A. (1996). *Challenges for the nuclear power industry and its regulators: The NRC perspective*. Speech presented at the Regulatory Information Conference, Washington, D. C., April 9.
- Jackson, S. E. (1992). Team composition in organizational settings: Issues in managing an increasingly diverse work force. S. Worshel, W. Wood, & J. A. Simpson, Eds. *Group process and productivity*. Sage, Newbury Park, CA.
- Jasper, J. M. (1990). *Nuclear politics: Energy and the state in the United States, Sweden, and France*. Princeton, NJ: Princeton U.
- Jehn, K. A., Northcraft, G. B., & Neale M. A. (1999). Why differences make a difference: A field study of diversity, conflict, and performance in workgroups. *Administrative Science Quarterly*, 44, 741-63.
- Kemeny, J. G., Babbitt, B., Haggerty, P. E., Lewis, C., Marks, P. A., Marrett, C. B., McBride, L., McPherson, H. C., Peterson, R. W., Pigford, T. H., Taylor, T. B., and Trunk, A. D. (1979). *Report of the President's commission on the accident at Three Mile Island*. New York: Pergamon.
- Kepner, C. H. & Tregoe, B. B. (1981). *The new rational manager*. Princeton, NJ: Princeton.

- Kim, D. H. (1993). The link between individual and organizational learning. *Sloan Management Review*, 35, 37-50.
- Kolb, D. A. (1984). *Experiential learning as the source of learning and development*. Englewood Cliffs, NJ: Prentice-Hall.
- Kramer, R. M. (1999). Trust and Distrust in Organizations: Emerging Perspectives, Enduring Questions. *Annual Review of Psychology*, 50, 569-98.
- LaPorte, T. R. & Consolini, P. M. (1991). Working in practice but not in theory: Theoretical challenges of "High-Reliability Organizations". *Journal of Public Administration Research*, 1(1), 19-47.
- Langer, E. J. (1975). The illusion of control. *Journal of Personality and Social Psychology*, 32, 311-28.
- Lanir, Z. (1986). *Fundamental surprise*. Eugene, OR: Decision Research.
- Lave, J. & Wenger, E. (1991). *Situated learning: Legitimate peripheral performance*. Cambridge, MA: Cambridge University.
- Levinthal, D. A. & March, J. G. (1993). The myopia of learning. *Strategic Management Journal*, 14, 95-112.
- Levitt, B. & March, J. G. (1988). Organizational learning. *Annual Review of Sociology*, 14, 319-340.
- Malone, T. W. & Smith, S. A. (1988). Modeling the performance of organizational structures. *Operations Research*, 36, 421-36.
- March, J. G. (1991). Exploration and exploitation in organizational learning. *Organization Science*, 2, 71-87.
- March, J. G. & Simon, H. (1958). *Organizations*. New York: Wiley.
- March, J. G., Sproull, L. Tamuz, M. (1991). Learning from samples of one or fewer. *Organization Science*, 2, 1-13.
- Marcus, A. A., Bromiley, P., and Nichols, M. (1989). *Organizational learning in high risk technologies: Evidence from the nuclear power industry*. Minneapolis: U. Minnesota Strategic Management Research Center, Discussion Paper #138.
- Miner, A. S. & Meziar, S. J. (1996). Ugly duckling no more: Past and futures of organizational learning research. *Organization Science*, 7, 88-99.
- Mirvis, P. H. (1996). Historical foundations of organizational learning. *Journal of Organizational Change Management*, 9, 13-31.
- Moreland, R. L. & Myaskovsky, L. (2000). Exploring the performance benefits of group training: Transactive memory or improved communication? *Organizational Behavior and Human Decision Processes*, 82, 117-33.
- Morris, M. W. & Moore, P. C. (2000). The lessons we (don't) learn: Counterfactual thinking and organizational accountability after a close call. *Administrative Science Quarterly*, 45, 737-65.
- Myers, I. B. & Myers, P. B. (1980). *Gifts differing*. Palo Alto, CA: Consulting Psychologists.
- Nelson, R. & Winter, S. (1981). *An evolutionary theory of economic change*. Cambridge, MA: Harvard U.
- Nisbett, R. E. & Ross, L. (1980). *Human inference: Strategies and shortcomings of social judgment*. Englewood Cliffs, NJ: Prentice-Hall.

- Nonaka, I. & Takeuchi, H. (1995). *The knowledge-creating company: How Japanese companies create the dynamics of innovation*. New York: Oxford University Press.
- Nutt, P. C. (1999). Surprising but true: Half the decisions in organizations fail. *Academy of Management Executive*, 13, 75-90.
- O'Reilly, C. A. (1978). The intentional distortion of information in organizational communication: A laboratory and field approach. *Human Relations*, 31, 173-93.
- Pan, S. L. & Scarbrough, H. (1999). Knowledge management in practice: An exploratory case study. *Technology Analysis and Strategic Management*, 11, 359-74.
- Perin, C. (1998). Operating as experimenting: Synthesizing engineering and scientific values in nuclear power production. *Science, Technology, and Human Values*, 23, 98-128.
- Perrow, C. (1970). *Organizational analysis: A sociological view*. Belmont, CA: Wadsworth.
- Perrow, C. (1984). *Normal accidents*. New York: Basic Books.
- Perrow, C. (1994). Accidents in high-risk systems. *Technology Studies*, 1, 1-19.
- Perron, M. J. & Friedlander, R. H. (1996). The effects of downsizing on safety in the CPI/HPI. *Process Safety Progress*, 15(1), 18-25.
- Pfeffer, J. (1982). *Organizations and organization theory*. Boston: Pitman.
- Popper, M. & Lipshitz, R. (1998). Organizational learning mechanisms: A structural and cultural approach to organizational learning. *Journal of Applied Behavioral Science*, .
- Pugh, D. S., Hickson, D. J., Hinings, C. R., & Turner, C. (1969). The context of organization structures. *Administrative Science Quarterly*, 14, 19-114.
- Quinn, R. E. & Cameron, K. (1983). Organizational life cycles and shifting criteria of effectiveness: Some preliminary evidence. *Management Science*, 29, 33-51.
- Rasmussen, J. (1990). The role of error in organizing behavior. *Ergonomics*, 33, 1185-1190.
- Rasmussen, J. & Batstone, R. (1991). *Toward improved safety control and risk management*. Washington, D.C.: World Bank.
- Reason, J. (1990). *Human error*. New York: Cambridge U.
- Reason, J. (1997). *Managing the risks of organizational accidents*. Brookfield, VT: Ashgate.
- Rees, J. V. (1994). *Hostages to each other: The transformation of nuclear safety since Three Mile Island*. Chicago: U. of Chicago.
- Roberts, K. H. (1990). Some characteristics of one type of high reliability organization. *Organization Science*, 2, 160-176.
- Rochlin, G. I. (1993). Defining "high reliability" organizations in practice: A taxonomic prologue. K. H. Roberts (Ed), *New challenges to understanding organizations*. New York: Macmillan.
- Rochlin, G. I. & von Meier, A. (1994). Nuclear power operations: A cross-cultural perspective. *Annual Review of Energy and the Environment*, 19, 153-187.
- Rooke, D. & Torbert, W. R. (1998). Organizational transformation as a function of CEO's developmental stage. *Organization Development Journal*, 16, 11-28.
- Royal Society (1992). *Risk: Analysis, perception, and management*. London: author.

- Rudolph, J. W., Taylor, S. S., & Foldy, E. G. (2000). Collaborative off-line reflection: A way to develop skill in action science and action inquiry. In P. Reason & H. Bradbury (Eds), *Handbook of action research*. Thousand Oaks: Sage.
- Sagan, S. D. (1993). *The limits of safety: Organizations, accidents, and nuclear weapons*. Princeton, NJ: Princeton University Press.
- Schaaf, T. W. Van der, Lucas, D. A., & Hale, A. R. eds. (1991). *Near miss reporting as a safety tool*. Butterworth-Heinemann, Oxford
- Schein, E. H. (1992). *Organizational culture and leadership, 2nd ed.* San Francisco: Jossey-Bass.
- Schein, E. H. (1996). The three cultures of management: Implications for organizational learning. *Sloan Management Review*, 38, 9-20.
- Schulman, P. R. (1993). The negotiated order of organizational reliability. *Administration and Society*, 25, 353-72.
- Senge, P. (1990). *The fifth discipline*. New York: Doubleday.
- Senge, P. & Sberman, J. D. (1991). Systems thinking and organizational learning: Acting locally and thinking globally in the organization of the future. In T. Kochan & M. Useem (Eds.), *Transforming organizations*. Oxford: Oxford University Press, pp. 353-370.
- Shrivastava, P. (1987). *Bhopal: Anatomy of a crisis*. New York: Basic Books.
- Sitkin, S. B. (1992). Learning through failure: The strategy of small losses. *Research in Organizational Behavior*, 14, 231-266.
- Sitkin, S. B., Sutcliffe, K. M., & Schroeder, R. G. (1994). Distinguishing control from learning in total quality management: A contingency perspective. *Academy of Management Review*, 18(3), 537-64.
- Star, S. L. (1989). The structure of ill-structured solutions: Boundary objects and heterogeneous distributed problem solving. In M. Huhns & L. Gasser (Eds.), *Readings in distributed artificial intelligence*. Menlo Park, CA: Morgan Kaufman.
- Tetlock, P. E. (1983). Cognitive style and political ideology. *Journal of Personality and Social Psychology*, 45, 118-126.
- Thorndike, E. L. (1911). *Animal intelligence*. New York: Macmillan.
- Torbert, W. R. (1972). *Learning from experience: Toward consciousness*. New York, Columbia University Press.
- Torbert, W. (1994). Cultivating post-formal adult development: Higher stages and contrasting interventions. In M. Miller & S. Cook-Greuter (Eds), *Transcendence and mature thought in adulthood: The further reaches of adult development*. Lanham, MD: Rowman & Littlefield.
- Turner, B. A. (1978). *Man-made disaster*. London: Wykeham.
- US Nuclear Regulatory Commission (1975). *Reactor safety study: An assessment of accident risks in US commercial nuclear power plants*. Washington, DC: US Nuclear Regulatory Commission Report, WASH-1400, NUREG-75/014.
- Vaughn, D. (1996). *The Challenger launch decision*. Chicago: U. Chicago.
- von Hippel, E. (1994). "Sticky information" and the locus of problem solving: Implications for innovation. *Management Science*, 40(4), 429-439.
- Webster, D. M. & Kruglanski, A. W. (1994). Individual differences in need for cognitive closure. *Journal of Personality and Social Psychology*, 67, 1049-62.

- Weick, K. E. (1987). Organizational culture as a source of high reliability. *California Management Review*, Winter, 112-127.
- Weick, K. E. (1995). *Sensemaking in organizations*. Thousand Oaks, CA: Sage.
- Weick, K. E. (1998). Improvisation as a mindset for organizational analysis. *Organization Science*, 9, 543-55.
- Weick, K. E. & Roberts, K. H. (1993). Collective mind in organizations: Heedful interrelating on flight decks. *Administrative Science Quarterly*, 3, 357-381.
- Weick, K. E., Sutcliffe, K. M. & Obstfeld, D. (1999). Organizing for high reliability: Processes of collective mindfulness. *Research in Organizational Behavior*, 21, 81-123.
- Westrum, R. (1988). *Organizational and inter-organizational thought*. Paper presented at the World Bank Conference on Safety Control and Risk Management.
- White, K. B. (1984). MIS project teams: An investigation of cognitive style implications. *MIS Quarterly* 95-101.
- White, P. A. (1988). Causal processing: Origins and development. *Psychological Bulletin*, 104, 36-52.
- Whitener, E. M., Brodt, S. E., Korsgaard M. A., & Werner, J. M. (1998). Managers as Initiators of Trust: An Exchange Relationship Framework for Understanding Managerial Trustworthy Behavior. *Academy of Management Review*, 23, 513-30.
- Wildavsky, A. (1988). *Searching for Safety*. New Brunswick, NJ: Transaction Press.
- Wood, W., S. Lundgren, J. A. Ouellette, S. Busceme, T. Blackstone. 1994. Minority influence: A meta-analytic review of social influence processes. *Psychological Bulletin*, 115, 323-45.
- Woods, D. D., Johannesen, L. J., Cook, R. I., & Sarter, N. B. (in press). *Behind human error: Cognitive systems, computers, and hindsight*. Wright-Patterson Air Force Base, OH: Crew Systems Ergonomics Information Analysis Center.
- Yan, A. & Louis, M. (1999). The migration of organizational functions to the work unit level: Buffering, spanning and bringing up boundaries. *Human Relations*, 52, 25-47.

Table 1  
Controlling and Rethinking Orientations

<b>Controlling</b>	<b>Rethinking</b>
Comply with rules	Challenge assumptions
Linear cause-effect	Nonlinear, dynamic
Find the root cause	Understand causal relationships
Decompose into components	Integrate systems
Mechanistic	Organic, human
Specialized experts	Collaboration
Inputs	Processes
Exploit what is known	Explore what is not known
Incremental	Radical
Variation reducing	Variation increasing
Convergent	Divergent
Uncertainty is a threat	Uncertainty is a learning opportunity
Anticipation; feed forward	Resilience; feedback
Fear and prevent bad events	Hope for and promote good results
Single-loop fixing	Double-loop reframing
Reactive, heroic fire fighting	Proactive, preventive, find better ways
Good managers have no problems	Good managers learn from problems
Blame others; keep secrets	Open exchange
Protect my fiefdom	Improve our plant
Short-term	Long-term
Compare to ourselves; trend	Compare to outsiders; benchmark

Figure 1  
Single- and Double-loop Learning

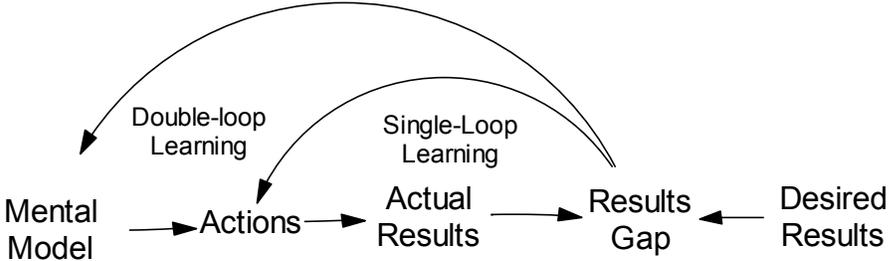


Figure 2  
The Four Stages of Organizational Learning

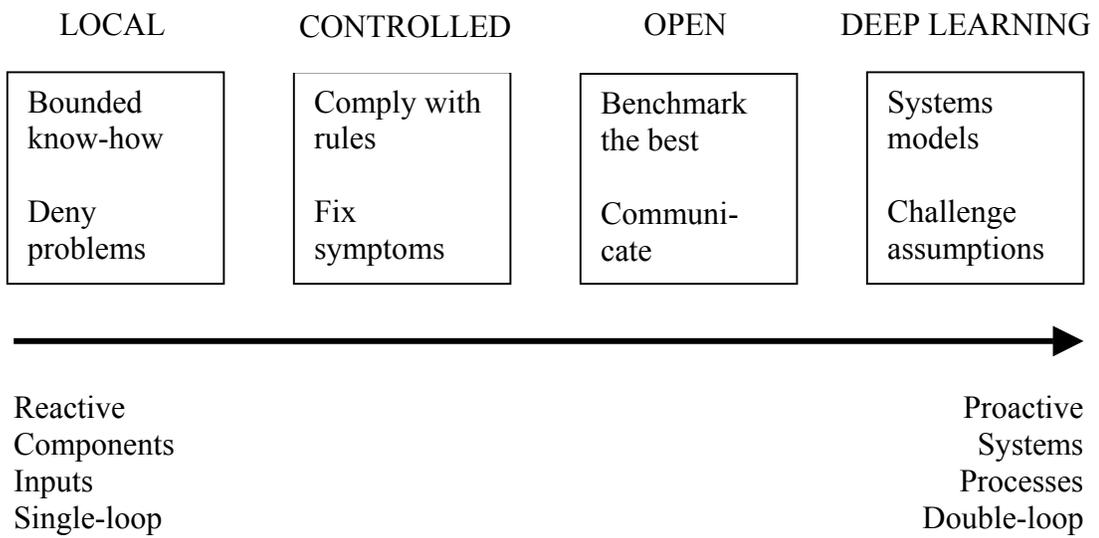


Figure 3  
 Framework For The Four Stages of Organizational Learning

