MIT Sloan School of Management

Working Paper 4360-02
March 2002

PROBLEM INVESTIGATIONS IN HIGH-HAZARD INDUSTRIES: CREATING AND NEGOTIATIONAL LEARNING

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Summary

High-hazard or high-reliability organizations are ideal for the study of organizational learning processes because of their intense mindfulness regarding problems. We examine 27 problem investigation teams at 3 nuclear power plants whose task was to report to management about causes and corrective actions and thereby contribute to organizational learning and change. Questionnaires were given to team members and manager recipients of the team reports, and team reports were coded regarding their analyses and recommendations. Our results showed variable depth and creativity in the reports, with better reports associated with more team training and experience, and more diversity of work experience. Ratings of report quality, individual learning, and plant changes by team members and managers suggested that reports were only partially effective as boundary objects to reach shared understanding and negotiate action plans. Team members rated their reports more favorably when they had better access to information and found generic lessons for the plant and failed barriers that could have prevented problems. Managers rated reports more favorably when the teams had more investigation experience, better access to information, and stronger corrective actions.

Problem Investigations in High-Hazard Industries:

Creating and Negotiating Organizational Learning [1]

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Introduction

Organizational learning is a critical function for organizations, especially in rapidly-changing environments (Aldrich, 1999; Weick *et al.*, 1999). Organizational learning is enacted through a variety of specific practices (Popper and Lipshitz, 1998) that support local innovation and meaning making, institutionalize new routines, and disseminate knowledge (Crossan *et al.*, 1999; Huber, 1991; Levitt and March, 1988). New meaning is constructed as work activities bridge communities of practice (Cook and Brown, 1999) or thought worlds (Dougherty, 1992) and people find new solutions to shared problems (Schein, 1992).

In this paper, we examine a specific organizational learning practice: problem investigations in the corrective action programs of nuclear power plants. Problem investigations use interviews, physical inspection, and document reviews to examine undesirable events or trends and draw lessons about underlying causes and ways to prevent future problems. Investigations are a form of off-line reflective practice

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(Schon, 1983; Rudolph *et al.*, 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. Although individuals investigate most problems, we focus on teams that are assigned the most persistent, causally ambiguous, and organizationally complex problems. Problem investigations are part of a corrective action program that starts with reporting of problems and continues with investigation of facts and 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 (Schaaf *et al.*, 1991).

Although plants devote considerable resources to investigations and improvement programs, they may not be learning as efficiently and effectively as they hope. Problem investigations in nuclear power plants (and other industries, Reason, 1990) tend toward shallow analyses and reestablishment of control (rather than learning, Sitkin *et al.*, 1994). Investigations tend to focus on one or a few causes that are proximal to the problem, typically involve technical faults or human agents, have available solutions that can easily be enacted, and are acceptable to powerful stakeholders (Carroll 1995, 1998; Rasmussen and Batstone, 1991). Further, team learning during investigations does not automatically lead to organizational learning and change: boundary spanning requires both willingness and effective practices (Ancona and Caldwell, 1992; Carlile, in press; Crossan *et al.*, 1999; Nutt, 1999; Popper and Lipshitz, 1998).

We examine three interrelated research questions regarding the investigation process and its relationship to organizational learning. We take as givens that the team task is to prepare a report with analyses and recommendations to management, that the team and managers may differ in their perceptions of the plant and its problems, that the report is intended to help management engage a change implementation process, and that the report feeds databases intended to capture organizational learning. In this context, first, how does the composition of the team, in terms of experience, training, and diversity of background, relate to team learning and the quality of the team report? Second, how does team learning relate to organizational learning and plant changes? Finally, how does the team report serve as a boundary object (Carlile, in press; Star, 1989) negotiated between the team and managers, a concrete and/or physical representation of knowledge that facilitates shared practice? Before exploring these research questions, we introduce the special challenges of learning in nuclear power plants and other high-hazard production systems.

Learning From Failure in High-Hazard Production Systems

Nuclear power plants and other high-hazard or high-reliability production systems (LaPorte and Consolini, 1991; Perrow, 1984) have distinct learning strategies (Weick *et al.*, 1999) arising from the need to understand complex interdependencies among systems (Perrow, 1994), and avoid both potential catastrophes associated with trial-and-error learning (Weick, 1987) and complacency that can arise in learning only from successes (Sitkin, 1992). Weick *et al.* (1999) argue that maintaining high reliability requires mindfulness comprised of attention to hazards and weak signals, a broad action repertoire, a willingness to consider alternatives, and reluctance to simplify interpretations.

Small failures, such as near-misses and incidents with minor consequences, may be good learning opportunities because they are less risky and less threatening, yet carry signal value for latent or hidden defects and potential chains of events that can propagate into disasters (Reason, 1990; Sitkin, 1992). In the decades following the accident at Three Mile Island, nuclear power plants have been encouraged by regulators and industry groups to become aware of a larger number of minor incidents and take action to avoid future trouble (Jackson, 1996; Rochlin, 1993). Plants that would have formally reported a few hundred incidents each year are now routinely reporting thousands of problems, and allocating resources to investigations on the basis of seriousness and learning potential. This process is widely considered to have helped the industry improve safety and reliability (e.g., Jackson, 1996), such that serious accidents are extremely rare.

Problem Investigations and Team Reports

The task of a problem investigation team is to gather and analyze information about the most serious and puzzling problems for the plant and to report their analyses and recommendations to managers, who then take action. These teams innovate and learn on behalf of the organization (Crossan *et al.*, 1999; Dougherty and Hardy, 1996; Huber, 1991), so greater team learning should lead to greater managerial learning and more effective plant changes. In Figure 1, we propose a simplified temporal ordering to these processes, starting from characteristics of the team and its access to information, continuing to team learning and its embodiment in the team report, and then to outcomes of the report, including management learning and change efforts that are intended to improve plant performance.

*** Insert Figure 1 ***

The investigation process is a type of "delegated participation" (Nutt, 1999), a frequently ineffective process in which representatives suggest solutions to managers who may resist implementation for various reasons. Managers hold cultural assumptions and values that typically emphasize results, short-term financial objectives, and avoidance of doubt or ambiguity (Carroll, 1998; Schein, 1996; Schulman, 1993). Teams may focus on their apparent task of finding causes (the investigation process is usually called "Root Cause Analysis") and offer unrealistic recommendations since they are less aware of strategic and resource issues. Thus, it is a considerable challenge to negotiate shared meaning between the investigation teams and the managers who rely on the teams for insights and recommendations.

The team report is a boundary object (Carlile, in press; Star, 1989) negotiated between the team and managers who request revisions and implement recommendations. Boundary objects offer a concrete means for team members and managers to specify and learn about their differences and dependencies through joint practice that collectively transforms knowledge. But the team negotiates from a weak power position (cf. minority influence, Wood *et al.*, 1994) and therefore has to sell (Dutton and Ashford, 1993) its ideas to managers who will implement change. The result may be a watered–down report or recommendations that are not fully implemented (Carroll *et al.,* in press) and therefore a missed opportunity for organizational learning.

Although the apparent function of the investigation is to issue a report that contributes to a change implementation process and databases intended to capture organizational learning, there are indirect ways that the investigation process may enhance organizational learning. Even if managers resist immediate changes, they may learn more about the plant and therefore be more receptive in the future. Individual team members may carry back to their workgroups both personal knowledge and social network links and thus enhance organizational learning capabilities (Cook and Brown, 1999; Gruenfeld *et al.*, 2000).

Propositions

Although we view our research as exploratory, in order to sharpen the analysis we offer four propositions based on the concepts presented above and intended to further articulate the research questions posed earlier. The propositions are linked to the conceptual framework in Figure 1 by numbers referencing relationships.

Proposition 1: a good team report should present a clear description of events, offer thoughtful analysis of underlying causes (Carroll, 1998; Reason, 1997), explore creative avenues for learning (Morris and Moore, 2000; Sitkin *et al.*, 1994), recommend corrective actions that are logically connected to the analysis (Kepner and Tregoe, 1981), and display a compelling narrative style to enhance impact.

Proposition 2: if there are differences between team members and managers in their judgments of report quality, managers are more likely to want actionable recommendations whereas team members are more likely to focus on discovering causes (Carroll, 1998; Nutt, 1999).

Proposition 3: teams with more task experience (years of work, appropriate training), more diverse functional experience (work history in more departments), and better access to information will learn more and write deeper, more creative, and more useful reports (Ancona and Caldwell, 1992; Bartunek, 1984; Jehn *et al.*, 1999; Weick, *et al.*, 1999).

Proposition 4: better reports will lead to more learning by managers and more plant change. The report captures at least some team learning, which is linked to both organizational and individual learning (Crossan *et al.*, 1999; Kim, 1993; Senge, 1990).

Contextual Sidebar

Industry and Organizational Context

Nuclear Power Plants and their Environment Nuclear power provides almost 20% of the electricity in the United States. During the 1990s when these data were collected, nuclear power plants were owned and operated by electric utilities, which typically owned other generating plants (coal, gas, hydro, etc.) and transmission lines. Nuclear power was highly regulated with the US Nuclear Regulatory Commission responsible for safety and separate state utility commissions responsible for rate setting. With the spread of deregulation, electric utilities began reorganizing to consolidate nuclear power plants into a small number of nuclear enterprises separate from other generating sources and distinct from the regulated transmission business.

Comment Nuclear power as a regulated industry developed a culture derived partly from fossil power plants and their craft workers, and partly from the nuclear navy that was the source of the technology. Plants were traditionally structured with clear hierarchies and separate functional departments such as operations, maintenance, design engineering, radiation protection, etc.

Method

Sample

Three nuclear power plants, owned and operated by three different utilities in two different regions of the country, agreed to cooperate, based primarily on prior contacts with the first author. One of the plants was generally considered by industry experts to be among the leaders at conducting problem investigations. Preliminary interviews were carried out at each plant to understand their problem investigation and corrective action process and to identify problems within the previous two years that had been investigated by teams.

35 problem investigation teams were identified from the prior two years, each of which had at least 3 team members who participated broadly in team activities and shared a perception of themselves as a team. Five teams were discarded due to incomplete questionnaire data and two had uncodable reports that used only a standardized report form without any causal narrative. Two investigations were combined into one because the same team performed both simultaneously on related problems.

Procedure

Once the teams were identified, questionnaires were distributed to team members and shortened questionnaires went to managers who identified themselves as sponsors or customers of the reports. Most team member questionnaires were distributed and collected in small group sessions; the remainder were handed out with return envelopes and received by mail. The questionnaire was strictly voluntary and confidential (in most cases anonymous). Most team members took approximately one hour to complete the questionnaire, although individuals who were members of multiple teams took longer. The response rate from team members was 83%.

Line managers who were the customers or sponsors of each report were asked to respond to a shortened version of the questionnaire. Since managers self-identified as customers and distributed the questionnaires among themselves, it is not possible to calculate a response rate. The team reports were also collected and coded.

Measures

The team member questionnaire had over 150 questions on the task, team process, results of the report, team member cognitive style, demographics, and work history. This paper focuses on a subset of questions relating to the quality of the report, investigation outcomes of personal learning and plant changes, and background information on team member demographics and work history. We defer analysis of team ratings of team process for a later paper, except for ratings of accessibility of information (see Appendix 1), which we consider to be the best available indicator of the difficulty of conducting the investigation. For simplicity, we do not report analyses of open-ended questions, although the responses contributed to our insights. We averaged the responses from team members by team, except for departmental affiliations, for which we counted the total number of distinct departmental affiliations on each team, once for current assignments and again for past positions.

Managers who self-identified as customers or sponsors of each report were asked to respond to a 33-item version of the questionnaire. For this paper, we analyzed only three items also asked of the team: the quality of the report, their personal learning, and plant changes. For teams with multiple manager responses, we again averaged the responses by team.

For the investigation reports, we developed coding categories and procedures through an iterative process of conceptual discussions among the research team, coding of pilot problem reviews, and revisions using *a priori* and grounded approaches (Miles and Huberman, 1994). We held several day-long meetings with Dr. William Corcoran, an experienced industry specialist in problem investigation programs, to review our coding protocol, code pilot problem reviews, and revise our coding criteria. 30 codes were generated and then grouped into thematic categories: causes, barriers/defenses, learning, corrective actions, and narrative features[2]. In three rounds of pilot testing, interrater agreement improved from 60% to 88%. 23 reports were coded by two coders, one an organization theorist, the other a nuclear engineer; differences of opinion were resolved by discussion. The organization theorist coded four reports after the other coder left the project.

Results

Preliminary Analyses: Data Reduction

Given the small number of problem investigation teams and the large number of items from questionnaires and report coding, we reduced the numbers of variables by

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[2] Causal analyses were judged on a four-point completeness scale from none to good; specific causes, corrective actions, and narrative features were judged on a five-point scale from none to very well; and barriers and learning were judged on a seven-point scale that integrated completeness and explicitness of causes identified.

creating composite variables (see Appendix 1) based on factor analyses and scale reliability analyses. The two questionnaire items measuring access to information formed a moderately reliable scale (α=.54). Twelve of the 30 report codes could be grouped into 3 dimensions (see Appendix 1): deep cause, out-of-the-box thinking, and narrative (clear, compelling storytelling). Four of the remaining 18 individual codes were retained that seemed important to organizational learning: failed barriers/defenses that could have prevented problems, generic lessons learned, corrective actions directed at fundamental problems, and corrective actions that connected logically to causes identified. We also examined the correlations of 14 demographic and work history variables with all measures of report quality, plant changes, and personal learning, and eliminated 4 that were never significant (age, gender, education, and proportion of engineers/scientists). We eliminated team size from the analysis because it was closely related to number of departments represented on the team (r=.78, p<.001). The remaining variables, shown in Table 1, consist of team member and manager ratings of report quality, individual learning, and plant change, seven ratings of the team report, team ratings of information access, and nine measures of work background. Finally, plant identity was used as a control variable in some analyses.

*** Insert Table 1 ***

In Fig. 2 we present an informal path model of the sequence of team and manager judgments about the report, plant changes, and their personal learning. We assumed that the team report could be a cause of change at the plant, as intended by the corrective action process. We further assumed that manager learning could be a result of the report, and could have an impact on plant change. Finally, we placed the team members' own learning prior in causal sequence to the report, under the assumption that the report captures some (but not all) of what the team members learn individually. This causal sequence will guide our analyses of the report and its impact on organizational learning.

*** Insert Fig. 2 ***

Team Member and Manager Ratings of the Team Report

Team members and managers judged whether, "Overall, the team produced an excellent report." On average, team members and managers thought the teams had produced good 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 (see Table 1, r=.18, n=27, n.s.).

Consistent with the lack of agreement in their reactions to the reports, team ratings and manager ratings had different patterns of relationships with other variables. More favorable team ratings (low scores were more favorable) were significantly associated (see Table 1) with team member ratings of better access to information (r=.64**), and our ratings of the report on finding failed barriers/defenses (r=-.56**) and generic lessons learned (r=-.42*). In order to confirm and refine these simple correlations, we ran a stepwise multiple regression model, with plant fixed effects controlled by dummy variables, using access and the work background variables. The results (see Fig. 2) showed that teams rated their reports better when they had identified failed barriers/defenses (β=-.55***), mentioned generic lessons learned (β=-.50***), had better access to information (β=.42***), and there were more departments represented on the team (β=.32*).

In contrast, for managers, more favorable ratings of the report were associated with corrective actions capable of addressing fundamental problems (r=-.42*) and team experience with investigations (r=-.38*). Stepwise multiple regression analysis controlling for plant revealed investigation experience (β=-.53**) and better access to information (β=.43*) as significant predictors (see Fig. 2). Note that, with plant controlled, investigation experience and corrective actions logically connected to causes had significant partial correlations; in the stepwise regression analysis, investigation experience entered first and suppressed logical corrective actions. Thus, there is some evidence that managers considered corrective actions, either logically connected to causes or directed at deeper issues, as an important aspect of the report. Although neither relationship was significant in stepwise multiple regression analysis, we have indicated their possible importance with dotted lines in Fig. 2 from logical corrective actions and fundamental corrective actions to manager ratings of the report.

These results partially support Proposition 1, in that team members rated reports significantly better that focused on failed barriers and lessons learned, and managers tended to rate reports better that focused on corrective actions to address problems. The differences between team members and managers are consistent with Proposition 2. Contrary to Proposition 1, neither team members nor managers rated reports better if the reports had a better narrative style or a deeper or more creative analysis.

Our Coding of Characteristics of the Team Report

Our coding of the reports showed a disappointing level of depth and completeness, insight and clarity. Most of the codes had means below the midpoint on our rating scales (see Table 1). Causal analyses rarely went very deep, for example, in one investigation of a worker who was injured falling through a roof, the root cause was either “tunnel vision” or “failure to use Accident Prevention Manual,” depending on which section of the report was consulted. The report did not discuss the sources of these behaviors. Corrective actions were sometimes misaligned with the supposed causes, either leaving root causes without corrective actions, or introducing corrective actions without specifying which causes they would address. Few reports were well-written -- they were sometimes confusing, often redundant, and usually in passive voice. Nor was there an overall positive relationship among characteristics of the report. As shown in Table 1, only about one-half of correlations among our seven variables were positive. The strongest were relationships among deep cause, out-of-the-box thinking, and corrective actions addressed to fundamental causes.

Since report characteristics of failed barriers/defenses, generic lessons learned, corrective actions capable of addressing fundamental causes, and corrective actions corresponding to causes were related to team or manager ratings of report excellence, we will start by analyzing their relationships with team inputs and process. As shown in Table 1, team reports that better articulated failed barriers/defenses had team members who had worked in more departments in the past (r=.46*) and more training in teamwork (r=.42*). In a stepwise multiple regression model controlling for plant, both remained significant (β =.48** and .46*, see Fig. 2). For generic lessons learned, there were significant correlations with more years in the plant (r=.60**) and fewer departments currently represented on the team (r=-.51**). This unexpected reverse relationship with functional diversity seems to be related to differences among plants, in that one plant had a required section of each report on lessons learned and also tended to use smaller teams with fewer departmental affiliations. In a stepwise regression analysis controlling for plant, as shown in Fig. 2, only years in the plant was significant (β= .38*).

Corrective actions logically related to causes did not correlate significantly with any of the predictors in Table 1, but with plant controlled, there was a significant relationship with years of industry experience (β=.35*, see Fig. 2). For corrective actions capable of addressing fundamental causes, there was a significant correlation with more years in the industry (r=.42*). In stepwise regression analysis controlling for plant (see Fig. 2), both years in the industry (β= .34*) and number of past departments represented on the team (β=.35*) were significant.

Our research team also believed that an excellent report should have deep causal analysis, out-of-the-box thinking, and a compelling narrative story. As shown in Table 1, deep cause was correlated significantly with more analysis training (r=.41*) and team members who had worked for more departments in the past (r=.38*). Since neither was significant in multiple regression analysis controlling for plant, we excluded deep cause from Fig. 2. Out-of-the-box thinking correlated significantly with fewer years in the military (r=-.54**) and more departments represented on the team (r=.55**). In multiple regression analysis controlling for plant, both remained significant (β=-.36* and .30*), as shown in Fig. 2. Finally, narrative had no significant correlations with predictor variables, but with plant controlled, there was a significant relationship with training in teamwork (β=.51*).

Overall, the above results are partially consistent with Proposition 3, in that variables related to training in teamwork, years of experience in the plant and the industry, and number of departments represented on the team, predict characteristics of the report. However, different measures of experience and departmental affiliation were related to different characteristics of the report, so that the general pattern is neither simple nor consistent. It is interesting that years in the military was negatively related to out-of-the-box thinking, suggesting that such experience was associated with some rigidity.

Organizational Change and Personal Learning

Both team members and managers were asked to agree or disagree with "As a result of the team report, the plant made changes and real improvements that have addressed the problems," and "I personally learned a lot about the plant" from the investigation. Team members and managers averaged between "slightly agree" and "moderately agree" on both questions (see Table 1), with less enthusiasm than for ratings of the report. Ratings of change by team members and managers correlate somewhat but not significantly (r=.33 in Table 1) and ratings of personal learning correlate even less strongly (r=.22). Interestingly, as shown in Table 1, team ratings of plant change correlate strongly with team ratings of the report (r=.62**) but team ratings of personal learning are uncorrelated with their ratings of the report (r=.06) or change (r=.13). In contrast, managers' ratings of organizational change and personal learning are highly correlated with each other (r=.57**) and with their ratings of the report (r=.59** and .53**). This provides qualified support for Proposition 4, the exception being that personal learning by team members was not related to report quality or plant changes. It also reinforces the separation of team learning from other aspects of organizational learning and change.

Team ratings that the plant made changes were correlated significantly with their ratings of the team report (r=.62**), access to information (r=.52**), finding failed barriers/defenses (r=-.40*), better narrative (r=-.45*), having more managers or supervisors on the team (r=-.47*), and more teamwork training (r=-.44*). In multiple regression analysis controlling for plant, the team report (β=.45**), more managers on the team (β=-.44**), and better narrative (β=-.31*) were significant predictors of team ratings of plant change (see Fig. 2).

In contrast, managers' ratings of change were correlated with their own ratings of the team report (r=.59**) and personal learning (r=.57**), our coding of the report having a better narrative (r=-.38*), and more team member training in investigation techniques (r=-.48*). In multiple regression analysis controlling for plant, reported in Fig. 2, both investigation training and rated report quality were significant (βs=-.63** and .51*).

Team ratings that members learned from the investigation were not correlated with any of our report coding or work characteristics. However, with plant controlled in multiple regression analysis, teams with fewer years of plant experience reported learning more (β=.50*). Managers' ratings of personal learning were correlated with managers' rating of report quality (r=.53**) and investigation experience on the team (r=-.55**). In multiple regression analysis controlling for plant, only prior investigation experience was significant (β=-.57**).

In summary, the factors that predicted rated plant change and personal learning were different for team members and managers. For team members, rated change was predicted by a better report, a clear narrative in the report, and managers on the team. This offers some support for Proposition 1 regarding the report narrative. Having managers on the team may have helped the team sell the report to managers, or it may have helped the team know about changes (many team members commented in interviews and open-ended questionnaire responses that they did not know about outcomes). Managers rated change as greater when they saw a better report and a team with more training in root cause analysis, supporting parts of Propositions 3 and 4. Personal learning was greater if the team members had less plant experience, suggesting that the investigation served a training function. Managers reported more learning when the team had more investigation experience, again supporting parts of Propositions 3 and 4.

Discussion

Our study of problem investigation teams illustrates how use of institutionalized organizational learning practices does not guarantee deep sensemaking and effective change. Reports can be helpful and insightful or shallow and confusing, depending on the skills, motivation, and support for the team. It is challenging to move from a set of practices aimed at search, transfer, and piecemeal change toward practices that support systemic knowledge generation among the team, managers, and the plant as a whole (Carroll *et al.*, in press).

Organizational learning practices require access to necessary resources (information, training, experience), diversity of inputs and viewpoints, and the ability to negotiate across disciplinary and hierarchical boundaries. In the action-oriented work environment of nuclear power plants, it is difficult to find time to reflect, and skills for reflection and for building shared mental models across disciplinary and hierarchical boundaries are not widespread. In particular, there appeared to be a disconnect between what teams thought they had learned and written into the report and what managers had understood from the team reports and investigations.

Team Reports as Boundary Objects

We naturally assumed that the problem investigation report would be an important part of the learning -- it is the official product of the group, the artifact that drives corrective actions and feeds databases. We thought that a better report would have a thorough causal analysis including fundamental causes in management, organization, and culture; corrective actions logically tied to the causal analysis and capable of addressing the fundamental causes; a strong learning orientation with imaginative ideas and approaches; and a good narrative to persuasively communicate its story to a wide audience of readers.

However, the three plants had disappointing levels of insight into their own problems, in terms of our coding of their reports and some of their open-ended comments and interview self-reports. Teams rarely looked for fundamental or deep, systemic causes, but they sometimes did a good job of addressing more proximal causes at an actionable level. Reports with more depth and creativity were associated with teams that had more experience in the industry but less in the military and represented more departments in their work history.

Team members and managers appeared to have learned different things from the investigation and reporting process, reflecting the differences in their thought worlds (Dougherty, 1992) or professional cultures (Schein, 1996) and the distinct content of knowledge reservoirs (Argote and Ingram, 2000). From the teams' viewpoint, a good report identified failed barriers and generic lessons, and was associated with a team that had access to information. From the managers' viewpoint, a good report came from a team with investigation experience and access to information, and included effective corrective actions. These differences in perspective may be effective for the overall goals of the plant, but they highlight the challenges of using team reports as boundary objects (Carlile, in press; Star, 1989) to enact a process of knowing (Cook and Brown, 1999) among team members and managers that can surface mental models of the work environment, compare them, and arrive at new, shared views.

We can offer some insights from our results into why incident investigation reports are only partially effective as boundary objects. First, delegated participation (Nutt, 1999) means that managers are not usually working with the team but are waiting to respond to a draft report. Thus, the team gets some benefit of the boundary object but negotiation is problematic with managers who have not fully participated in the joint work. Second, the use of the boundary object to sharpen and then bridge differences depends on rigorous attention to a shared approach. Some problems, investigation approaches, and solutions are concrete and easy to share, but others are not. The meaning of "root cause analysis" is not as clear and standardized as it appears. As we noted, reports were rather casual in connecting causes and recommended actions. It takes mindful attention to build shared understanding around diffuse issues such as “culture” and “accountability” that have very different meanings and implications to professional groups (Carroll, 1998; Carroll *et al.*, in press). Unless the team and managers work hard to clarify meaning and build shared mental models, they may erode to opportunity to deepen their understanding and produce organizational learning and change.

One outstanding positive example was a report from the well-regarded plant that offered an explicit description of the negotiation process between the team and its management customers. The team initially made over twenty recommendations, which management evaluated and reduced to six, only four of which were implemented. The report provided a uniquely candid discussion of managers’ cost-benefit analyses. The reports from this plant seemed generally more explicit about differences of opinion and specific factual arguments than reports from the other plants, perhaps because the Plant Manager was more supportive of learning.

From Team to Organizational Learning

Organizational learning in the form of changes to routines and physical equipment depends upon managers implementing actions 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. For example, in the team investigation of the worker who fell through a roof, a team member wrote, “Management took renewed emphasis on safety. Procedures (pre-job briefs) were changed and working aloft programs were implemented.” However, team members frequently reported not knowing what had happened, or that management had been defensive and therefore reports had been less than candid. One team member wrote, "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!"

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 training and experience. 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 and to establish strong relationships with other groups in order to get information and later to sell the report (Ancona and Caldwell, 1992; Dougherty and Hardy, 1996; Dutton and Ashford, 1993).

Implications

Our results illustrate the importance of a detailed examination of specific learning practices. Team members and managers did not fully share an understanding of what was learned in the report and negotiations over the report were not always effective. Although plant personnel may wish to allocate responsibilities such that teams and managers have different objectives and information, well-intentioned procedures for investigations and implementation may produce disappointing benefits if there is a failure to bridge hierarchical boundaries and communities of practice. Managers appeared to seek logical and practical solutions to problems, not highly complex analyses and recommendations to "solve world hunger" (a phrase from our interviews). 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).

However, consistent with our propositions, access to information (and boundary spanning activities in general) and team experience were both beneficial for report quality and organizational learning. Having a multidiscipline team with experience in many departments of the plant probably contributes to the breadth of experience within the team and credibility with multiple audiences that enhances access to information and buy-in to the recommendations. Having managers or supervisors on the team also was related to team ratings of change but not managers’ ratings of change, suggesting that this may have helped give the team more information about what was actually done as well as help bridge the boundary between the team and managers.

From a practical standpoint, there are many implications for team composition and training and the process of linking team and organizational learning. Multidicipline teams bring better access to information and breadth of knowledge, but need support to overcome misunderstandings and potential conflict (cf., Jehn *et al.*, 1999). Individuals and teams benefit from more training and practice, but centralizing investigations in a specialized staff group reduces line management participation and commitment to change (Nutt, 1999). Decentralization reduces the direct benefit of a more expert report but increases the indirect benefits of team members returning to their work groups with their new knowledge (e.g., those with the least plant experience reported learning the most) and extended networks (Gruenfeld *et al.*, 2000). Management involvement in the investigation and in the negotiation of report content must be taken seriously. At one chemical company we visited, problem investigation activities have the explicit goal of educating managers, not solving problems! This company makes managers collectively responsible to understand problems in context, discuss improvement opportunities, commission solution development activities, and implement changes.

Limitations and Future Research

We recognize that our results are more exploratory than confirmatory. With so few teams and so many measured variables, the results need replication. Many of the concepts that are important to our theory, such as learning and change, were measured only indirectly by self-reports and coding of the team report. Coding of the team report misses aspects of the learning in the conversations and reporting process that surrounds the artifact of the report. Further, the self-report measures were retrospective and therefore subject to bias and distortion. Future research should incorporate direct observation and longitudinal designs. Despite the limitations, however, the pattern of results is generally consistent, supported by open-ended comments and interview data, and provocative for developing new connections for theory, research, and practice.

Acknowledgements

This research was supported by National Science Foundation grants SBR96-1779 and SBR98-11451 and a Marvin Bower Fellowship at the Harvard Business School. We greatly appreciate the cooperation of the nuclear power 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. Deborah Ancona and Paul Carlile offered comments on earlier drafts.

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Table 1

Descriptive Statistics and Correlations

	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1.*teamreport*	1.80	0.58																						
2.*mgrreport*	2.12	0.90	.18																					
3.*teamchange*	2.30	0.75	.62	.33																				
4.*mgrchange*	2.32	0.82	.23	.59	.33																			
5.*teamlearn*	2.66	0.83	.13	.10	.06	.02																		
6.*mgrlearn*	2.36	0.93	.00	.53	.20	.57	.22																	
7.barriers	3.24	1.53	-.56	-.16	-.40	-.27	-.09	-.19																
8.fundcoract	1.85	0.55	.03	-.42	.06	-.31	.10	-.32	.37															
9.logical	3.00	0.88	.03	-.32	.02	-.09	.29	-.03	.12	.22														
10.generic	3.41	1.47	-.43	.08	-.19	.08	-.20	.04	-.13	-.35	-.30													
11.narrative	13.14	2.03	-.25	-.22	-.45	-.38	.23	-.07	.41	.22	-.04	-.17												
12.outbox	7.84	3.08	.06	-.15	.18	-.14	.09	-.05	.30	.64	.25	-.33	.21											
13.deepcause	10.05	3.17	-.03	-.10	-.01	-.16	-.07	-.25	.38	.67	-.12	-.12	.33	.39										
14.*access*	2.07	0.61	.64	.25	.52	.20	-.13	-.02	-.33	-.04	-.08	-.10	-.22	.13	-.01									
15.yrsmilitary	1.42	1.25	.19	-.07	-.02	.08	-.10	-.02	-.32	-.30	-.26	.22	.24	-.54	-.03	.09								
16.yrsplant	13.70	4.15	-.27	.06	-.18	.27	.23	.09	-.18	-.31	-.06	.60	-.01	-.37	-.24	-.24	.26							
17.yrsindustry	18.75	2.67	.05	-.29	-.15	.04	.30	-.14	.11	.42	.24	-.16	.15	.18	.26	-.16	.13	.10						
18.manager	0.28	0.24	-.04	-.16	-.47	.05	-.28	-.04	.26	.08	.14	-.37	.15	.07	.11	-.14	-.07	-.28	.38					
19.depts	3.33	1.78	.32	.07	.26	.10	-.13	.19	.20	.31	.31	-.51	.05	.55	.06	.13	-.32	-.47	-.11	.30				
20.deptspast	4.70	2.05	-.23	.03	-.22	-.01	-.37	-.25	.46	.35	-.16	.03	.26	.26	.38	-.06	.07	-.02	.10	.23	.33			
21.investigatns	2.35	0.61	-.03	-.38	-.18	-.33	-.31	-.55	.10	.05	-.09	.17	.01	-.10	.17	.19	.20	-.13	.01	.11	-.35	.08		
22.analystrain	2.07	0.66	.01	-.14	.10	-.48	-.05	-.35	.09	.26	-.22	.16	.27	.17	.41	.19	.30	-.11	.16	-.30	-.18	.31	.40	
23.teamtrain	2.38	0.57	-.34	.04	-.44	-.26	.01	-.29	.42	-.18	-.09	.29	.29	-.32	-.02	-.14	.18	.32	-.00	.04	-.32	.14	.25	.12

Note - correlations larger than .381 are $p<.05$, those larger than .487 are $p<.01$; variables in *italics* are reverse coded

Figure 1
Conceptual Relationships Between Team Reports, Learning, and Change

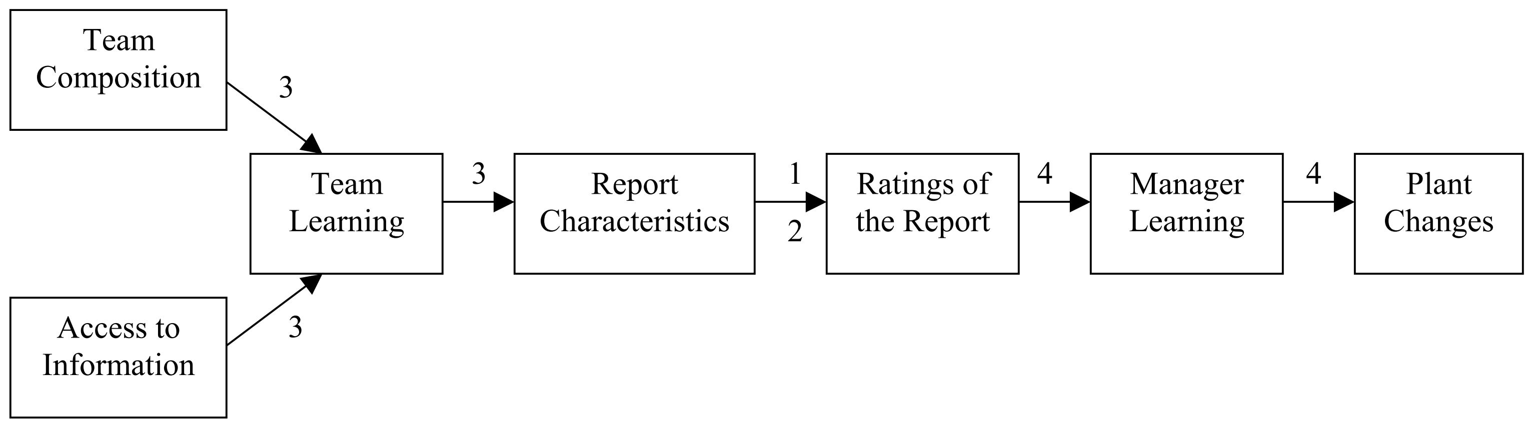
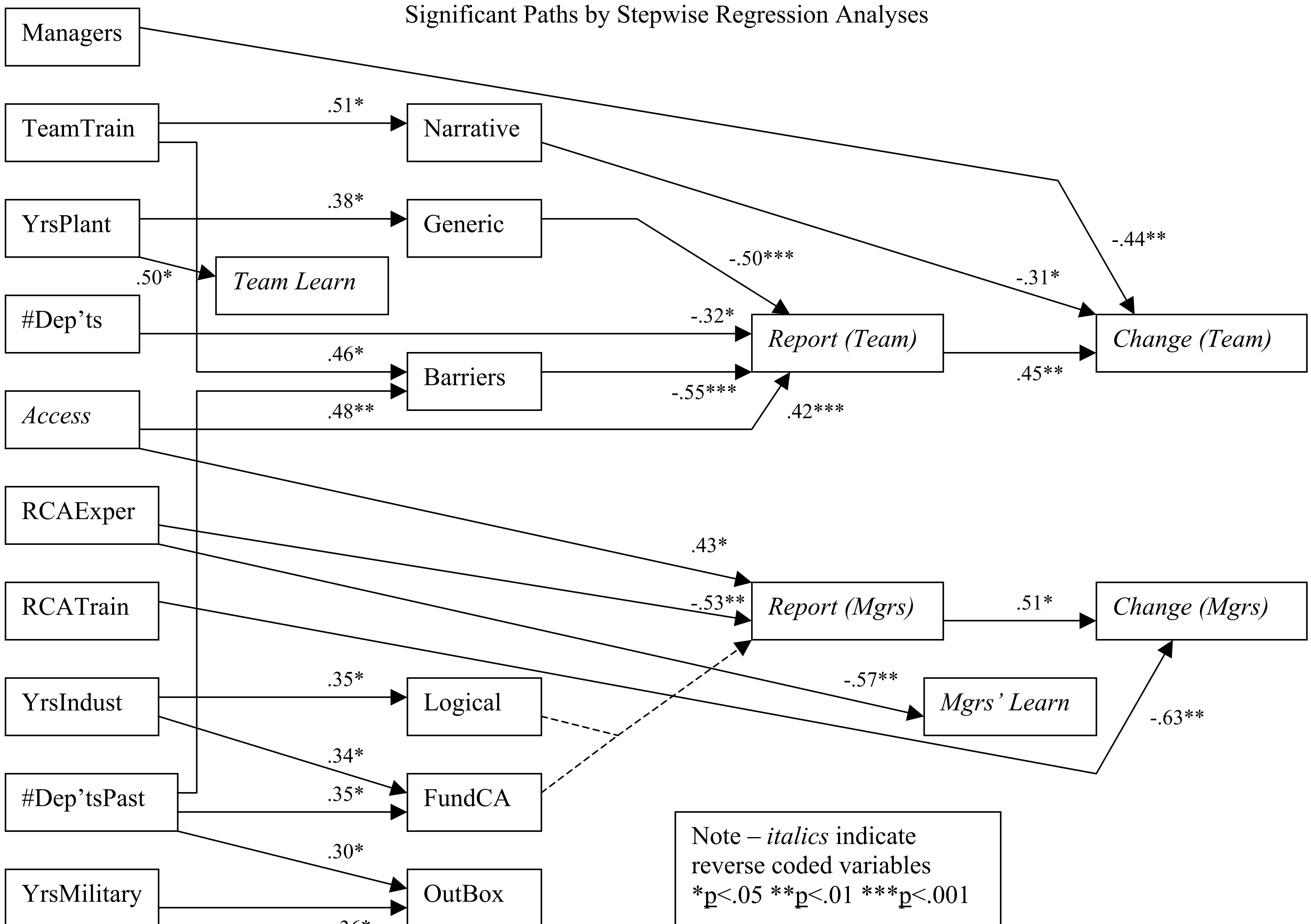


Figure 2
Significant Paths by Stepwise Regression Analyses



Appendix 1

Composite Scales From Questionnaires and Report Coding

Composite	**Items**
Access (.54)	We were able to get all the information we needed to do our work. Everyone the team approached gave as much of their time as the team needed.
Narrative (.43)	The report tells a memorable story. The narrative is easy to follow. The causal chain of events leading to the incident is clear.
DeepCause (.79)	The causal chain of events leading to the incident is complete. The report has an integrative explanation for various levels of causes, e.g., links fundamental to surface causes. The role of plant management's priorities is mentioned The role of plant and/or industry culture, tradition, paradigms in the incident is examined. The report identifies failures of oversight (by e.g. supervisors, executives, health physics, internal quality control or external parties) that didn't recognize underlying weaknesses in the plant's systems that may have led to the incident.
Out-of-box (.75)	The report identifies previous formally processed events whose corrective actions should have prevented this incident, i.e., failures to learn. The report uses interdisciplinary and/or cross context approaches to researching the problem (e.g., industry best practices, other departments in the plant). The corrective actions suggest alternatives to existing requirements that might rectify similar problems in the future. The report describes the role of existing informal routines in causing the incident.

Note – team-level reliabilities are given in parentheses. The reliability for Access across individuals was .58.