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PROCESS MAPPING AND SHARED COGNITION: TEAMWORK AND THE DEVELOPMENT OF SHARED PROBLEM MODELS

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As we enter the 21st century, work teams continue to be a dominant force in industry (e.g., Cannon-Bowers, Oser, & Flanagan, 1998; Guzzo & Salas, 1995). Teams are formed for a diverse range of tasks, from creating product marketing strategies to implementing change management procedures, and their life expectancy can vary from the duration of a given meeting to the duration of a corporation. Because of this prevalence of teams in industry today, many are formed without much forethought along with the expectation that only gains in productivity can result from teamwork (Hackman, 1990). The reality is that there is little guarantee of success, as many teams fail for any number of reasons (e.g., Hackman, 1998; Tanskanen,

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Buhanist, & Kostama, 1998). In this chapter we link theoretical approaches from cognitive science on the nature of problem solving with research in team performance to illustrate how certain process interventions may facilitate team performance through the development of shared problem models.

The literature on team performance and shared mental models, while not lacking in theory, has far fewer methodologies that may foster their development. Only in the last few years have systematic attempts to train shared mental models been empirically examined (e.g., Marks, Zaccaro, & Mathieu, 2000; Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000; Smith-Jentsch, Campbell, Milanovich, & Reynolds, 2001). Nonetheless, in industry, armies of consultants continually apply any number of tools in their attempts to improve organizational effectiveness. Unfortunately, while the utility of such tools often seems intuitively obvious, they are typically applied at a rate that vastly outpaces the research necessary to fully capitalize on their strengths while limiting their weaknesses. Because of this, the overarching problem facing many is that much ambiguity exists about not only the appropriateness of such tools but also why they may, or may not, be effective. A systematic attempt to link theory and research from cognitive and organizational psychology may assist in not only the development of new tools based on theory but also the analysis of current tools to understand what drives their success and limit what may be their failings. Therefore, to the degree that the research community can focus attention on this issue in an attempt to maximize the utility of and minimize the costs associated with such tools, organizational effectiveness may be better fostered. As an illustration of how this may proceed, we conduct a descriptive analysis of one such tool and discuss how it may be contributing to increases in team effectiveness.

In this chapter we first review the problem-solving process and discuss how shared mental model theory has been applied to explain how teams can often overcome barriers to effective performance. We then discuss process mapping, a tool designed to assist problem-solving teams overcome some of the limitations that can lead to failure while, at the same time, capitalizing on factors that can lead to success. We argue that this tool, originally developed to assist teams in process redesign and organizational change (e.g., Rummler & Brache, 1995), is successful because it leads to the construction of a shared mental model of the problem in question (Cannon-Bowers, Salas, & Converse, 1993). Our discussion centers on the notion that, to the degree the team task requires the construction of a shared understanding, external representational tools can act as a scaffolding to facilitate the building of that shared representation.

Types and definitions of teams vary somewhat, from "interdependent collections of individuals who share responsibility for specific outcomes for their organizations" (Sundstrom, De Meuse, & Futrell, 1990, p. 120) to "two or more people who interact dynamically, interdependently and adaptively toward" a shared goal (Salas, Dickinson, Converse, & Tannenbaum, 1992, p. 4). Our discussion in this chapter focuses only on problem-solving teams. Problem-solving teams are typically established for short-term situations that require relatively rapid action be taken against specific workplace problems. Furthermore, such teams often possess a diverse membership, composed of members from a variety of functional areas (see Moreland, Levine, & Wingert, 1996, for a discussion of issues in group composition). As such, they represent a particularly challenging form of team structure given that they possess a compressed developmental life span and heterogeneous composition, the combination of which potentially exacerbates problems arising from group dynamics. In sum, although numerous definitions of teams have been offered, problem-solving teams do meet the apparent defining criteria by being composed of members with complementary skills who maintain a degree of interdependence by the fact that their overall task goal (i.e., resolution of an organizational problem) requires cooperative interaction (e.g., Fleishman & Zaccaro, 1992; Katzenbach & Smith, 1993). We next discuss the problem-solving process, emphasizing problem conceptualization and its import to team problem solving.

TEAMS AND PROBLEM CONCEPTUALIZATION

An old management axiom states that "a problem defined is half solved." Problem solving, then, could be said to involve a substantial reflective component in that successful problem resolution requires adequate problem definition. Indeed, research from cognitive science comparing expert–novice problem solving finds that experts in a particular field spend a considerable amount of time representing a problem before attempting to solve it (e.g., Chi, Glaser, & Rees, 1982). The issue of problem representation is foundational to theories of problem solving (e.g., Newell & Simon, 1972), and it becomes even more critical when talking about problem-solving teams. Specifically, because teamwork, by its very definition, involves a collaborative component, team performance is a function of the level of understanding the team shares about their task and their capabilities. Researchers in team problem solving argue that "before a decision can be made, the [team] must first recognize that a problem exists, determine its nature, and determine the desired outcome" (Orasanu, 1994, p. 256). Nonetheless, despite the criticality of fully understanding the nature of a problem prior to beginning the solution generation phase, research has long demonstrated that teams show little inclination to engage in this aspect of the problem-solving task (e.g., Hackman & Morris, 1975). Furthermore, Moreland and Levine (1992), in their article on problem identification in teams, cited a surprising paucity of research on teams and this process.

Problem-Solving Stages

Cognitive scientists have identified several distinct stages involved in problem solving, each of which requires unique approaches to be successfully resolved. For example, problem solving is said to involve a search through a hypothesis generation space and a hypothesis testing space (Klahr & Dunbar, 1988; Simon & Lea, 1974), and successful solution generation takes place through a number of interdependent processes (see also Klahr, Fay, & Dunbar, 1993; Schooler, Fallshore, & Fiore, 1995). Others have focused on the stages occurring prior to hypothesis generation. For example, problem identification or problem sensing involves initial apperception that a potential problem exists or may shortly occur (Cowan, 1986; Klein, 1993; Klein & Pierce, 2001; Klein, Pliske, Crandall, & Woods, 1999; Moreland & Levine, 1992). In such a case, stimuli in one's environment are constantly monitored, and one scans for cues suggesting abnormalities. After this stage, one would move to the problem conceptualization stage, the stage after which a problem has been recognized and prior to attempts to generate a solution. During problem conceptualization, the problem solver describes and diagnoses the problem that has been recognized.

We wish to clearly distinguish between the problem identification and problem conceptualization stages. Problem identification in teams is thought to occur only when the members realize that other team members are aware of the problem (Larson & Christensen, 1993; Moreland & Levine, 1992). In particular, "no meaningful interactive problem-solving activity can take place without members first becoming cognizant of the fact that others in the group perceive the problem" (Larson & Christensen, 1993, p. 9). Only then would problem conceptualization proceed appropriately. While not denying the criticality of the problem identification process, we focus on problem conceptualization specifically because a problem improperly conceptualized is unlikely to be solved.

Problem Conceptualization

The stage of problem conceptualization can be said to involve the construction of a *problem space*. Problem space theory, initially developed from information-processing theories of human problem solving (e.g., Newell & Simon, 1972), has only recently been applied to group interaction processes (e.g., Fiore, 2000; Fiore & Schooler, 2001; Hinsz, Tindale, & Vollrath, 1997). The problem space can be considered to be the mental space in which the problem solver must encode the

> problem elements—defining goals, rules and other aspects of the situation . . . [that] represents the initial situation presented to him, the desired goal situation, various intermediate states, imagined or experienced,

as well as any concepts he uses to describe these situations to himself. (Newell & Simon, 1972, p. 59)

Constructing the problem space is a necessary, but not sufficient, factor in team problem solving. What is mandatory for effective team problem solving is that this conceptualization is shared; that is, a team's comprehension of the critical problem components contains a substantial amount of overlap (e.g., Orasanu, 1994). Although one could argue that problem solving may be facilitated by differing problem conceptualizations (e.g., by bringing diverse viewpoints into the process), we suggest that, for team problem solving to take advantage of a heterogeneous group composition, they must first be in agreement as to what the problem is. Thus, we do not suggest that a team be homogeneous with respect to their problem-solving approaches (Janis, 1972), rather, that they share an understanding of the critical problem elements.

For a team to accurately assess their problem situation, that is, adequately search their problem space, they must overcome limitations inherent in group problem solving. For example, for the team to coordinate their efforts during the problem-solving process (and be able to take advantage of diverse input), they must share a commensurate understanding of the problem itself. Although some literature does suggest that certain conceptualization processes such as planning are not always beneficial (e.g., Wittenbaum, Vaughan, & Stasser, 1998), these findings apply primarily to tasks requiring little coordination. Similarly, some research documents that groups may engage in tacit coordination (e.g., Wittenbaum, Stasser, & Merry, 1996) rather than explicitly coordinate their processes. But, within the context of teams engaged in complex problem solving, tacit coordination or a lack of planning could lead to the construction of either an incorrect or incomplete conceptualization of the problem. From the standpoint of team cognition, our argument is that, without a shared understanding of what the problem is, not only may a team be solving the wrong problem, but they also cannot make full use of their resources, the very reason teams are assembled in the first place. We turn next to a brief discussion of the shared mental model construct and follow this with an explication of how components of shared problem models fit well with the mental model construct. We then describe how it is that process mapping helps problem-solving teams to develop shared models for the conceptualized problem.

SHARED MENTAL MODELS AND TEAM PERFORMANCE

In this section we discuss how notions of shared cognition have been applied to explain successful team performance in a variety of task situations. *Shared cognition* is the term used to describe how processes at the intraindividual level are dependent on and interact with processes at the interindividual level (e.g., Cannon-Bowers & Salas, 1990; Levine, Resnick, & Higgins, 1993). Development of shared cognition theories arose out of the social cognition movement. Although definitions vary, social cognition can be defined as "those social processes . . . that relate to the acquisition, storage, transmission, manipulation and use of information for the purpose of creating a group-level intellective product" (Larson & Christensen, 1993, p. 6). As this definition suggests, groups are sometimes considered to be information-processing units (Hinsz et al., 1997) in a manner analogous to early views of human cognition (e.g., Newell & Simon, 1972). We focus on one aspect of shared cognition—shared problem models—specifically because a growing body of research demonstrates how such models directly impact team performance.

Definitions of mental models vary somewhat, often depending on the domain in question. In the cognitive science literature, mental models are involved in the comprehension of a given phenomenon as one integrates knowledge, and they facilitate one's ability to draw inferences (e.g., Johnson-Laird, 1983); they are also thought to be the interface between procedural and declarative knowledge (e.g., Glaser & Bassok, 1989). Similar notions are proposed by human factors researchers who argue that mental models allow users to generate descriptions of a system and make predictions about future system states (e.g., Rouse, 1989). From the organizational psychology literature, mental models are said to be representations of knowledge elements in an employee's environment along with the elements' interrelations (Klimoski & Mohammed, 1994; Mohammed & Dumville, 2001). In the team training literature, researchers argue that, through effective training and teamwork (e.g., cross-training, information transfer), a "shared" understanding of a task situation develops (e.g., Cannon-Bowers et al., 1993; Stout, Cannon-Bowers, & Salas, 1996). Notions of shared understanding have recently come to the forefront of research on teams because efficient and effective team performance is often shown to be related to the degree that team members agree on, or are aware of, task, role, and problem characteristics (Cannon-Bowers et al., 1993; Fiore, Salas, & Cannon-Bowers, 2001; Marks et al., 2000; Mathieu et al., 2000). For example, shared problem or task models consist of situation- and task-appropriate strategies for interpreting and acting on a variety of task situations (e.g., Klimoski & Mohammed, 1994; Orasanu & Salas, 1993), and they are thought to facilitate team coordination.

Defining Shared Mental Models

Although the exact nature of shared mental models is still in debate, a number of critical factors have been identified and we focus on three of these factors directly relevant to effective performance for problem-solving teams. More specifically, reviews of the literature concerning team mental models note that several factors need to be present to make the claim for a shared mental model (e.g., Cannon-Bowers et al., 1993; Klimoski & Mohammed, 1994). To have a shared model for a team task means to be aware of the following: problem structure, the roles and skills of the team as they pertain to the problem, and the shared awareness that each member of the team possesses this knowledge. We suggest that the successful development of these components within problem-solving teams will facilitate the overall problem conceptualization process.

First is the notion of a shared problem structure. A shared problem structure can be considered to consist of overlapping organized knowledge held by team members (e.g., Resnick, 1991). This can consist of organized declarative or procedural knowledge concerning the problem and decision rules associated with the problem (Cannon-Bowers et al., 1993). Thus, when a team possesses awareness of the problem *structure*, they are more likely to later develop an effective problem *solution* (e.g., Maier, 1967).

Second is the notion that shared mental models consist of an understanding of each team member's roles and skills. This has been labeled *interpositional* knowledge, and an absence of such knowledge is linked to failures in team effectiveness (Volpe, Cannon-Bowers, Salas, & Spector, 1996). Furthermore, the success of cross-training programs, or training designed to encourage compatible mental models with respect to team member roles and responsibilities, has been linked to increases in shared interpositional knowledge (e.g., Blickensderfer, Cannon-Bowers, & Salas, 1998; Marks et al., 2000; Mathieu et al., 2000). To the degree that the team is fully aware of member idiosyncrasies (e.g., Moreland & Levine, 1992), the unique capabilities of each team member can be fully exploited. Thus, this may help the team overcome information-sharing problems sometimes experienced during team interaction (e.g., Hollingshead, 1996; Stasser, Stewart, & Wittenbaum, 1995; Straus, 1996) and is similar to notions of "transactive memory systems" proposed by Moreland and colleagues (e.g., Liang, Moreland, & Argote, 1995; Moreland & Argote, 2003; Moreland & Myaskovsky, 2000).

The aforementioned issues relate directly to our third factor, specifically, a shared understanding of the problem requires explicitly defining the problem (e.g., articulating plans and strategies), and it ensures that all participants are solving the same problem. This has been described as the development of a shared problem model and is linked to effective team communication whereby members become equally aware that the team understands the problem (Orasanu, 1994). Furthermore, the team explicitly negotiates their shared understanding of the problem, a step argued to be critical for truly shared mental models (Levine et al., 1993).

Summary

As the brief review highlights, the development of shared mental models attenuates some of the interaction problems teams sometimes experience.

In the next section we link these components of shared mental models to an instantiation of shared problem models. We do so with an example of a popular management tool and demonstrate how certain limitations inherent in teamwork can be overcome through the use of this tool. Our overall goal is to show how theoretical and applied research can be productively intermixed in a way conducive to organizational effectiveness. Furthermore, while the use of problem-solving tools is continuously touted in industry, theoretical accounts of why they work (or do not work) are lacking. As such, this chapter represents an attempt to clarify how one such tool (i.e., process mapping) can facilitate problem conceptualization and subsequent problem solving. We now turn to a discussion of process mapping, a tool widely used in industry (e.g., Rummler & Brache, 1995) to help cross-functional teams on the initial stages of their problem solving.

PROCESS MAPPING AND PROBLEM-SOLVING TEAMS

Although the utility of shared mental models is clear with respect to teams operating in dynamic environments with a high degree of interdependence, we suggest that such models are critical in any team environment. In particular, we argue that many teams work under the unwarranted assumption that they have a shared understanding of their team task. Because they may have either only partial shared understanding or an understanding lacking in any agreement, their ability to effectively work through a problem is severely hindered. We suggest that process mapping works as a problem-solving tool because it leads to the construction of a shared mental model of the problem. Specifically, process mapping scaffolds team cognition in that it facilitates the scanning of the problem space, ensuring that all elements are accounted for, agreed on, and thus, properly addressed.

Process mapping was initially developed to assist teams in process redesign being implemented in the context of organizational improvement (e.g., Rummler & Brache, 1995). Essentially, the technique involves developing a representation of the work flow involved with a given process. In this context, a process is defined as "any combination of people, machines, materials, and methods that is aimed at manufacturing a product or performing a service" (Symons & Jacobs, 1997, p. 71). Thus, process maps are representational charts that fully delineate the process and are descriptive models of a process rather than normative models (although normative models are later defined as the problem-solving process continues).

Initially, process mapping requires the assembly of cross-functional teams, with members selected from every department involved in a given process. The first step is the creation of what is known as the "as is" map, a map detailing the process in its current incarnation. Such a map consists of a visual representation of the personnel or departments involved in the process, along with an articulation of the steps along the process. Constructing this "as is" map is typically a lengthy process because it involves classification of not only every phase of the process but also any illogical, missing, or redundant steps in the process (termed *disconnects*). Thus, the "as is" map represents the critical step in the problem conceptualization stage. Only after the team is agreed that all steps and all disconnects have been labeled do they then focus on what is called the "should be" map. This map is the idealized representation of the new process in which the disconnects have been removed. The overall goal of the construction of the "as is" and "should be" maps is an attempt to eliminate nonvalue-added steps, wherein the remaining steps are redefined for more efficiency; that is, the "should be" map represents the normative model of the process.

Across differing industrial sectors, the data suggest that this tool significantly improves the efficiency of a given process by reducing throughput time. For example, in product development processes, cycle time has been reduced anywhere from 39% to 75% (Anjard, 1996). Manufacturing reengineering efforts using process maps have also shown dramatic effects (Aldowaisan & Gaafar, 1999) with efforts by one process improvement team leading to a reduction in product installation time by 50% (Mason, 1997). Through the use of process mapping to simplify manufacturing procedures, one team found that errors were decreased to 2% of their initial level (Symons & Jacobs, 1997). Furthermore, in some situations, improvements in administrative or service processes can be as high as 90% (see Loew & Hurley, 1995, for a discussion).

PROCESS MAPPING AND PROCESS MAPS AS SHARED MENTAL MODELS

In this section we illustrate how, in the construction of the process map, the team may actually develop a shared problem model for the process in question. We do this by illustrating how it is that process mapping may help teams overcome situations typically hindering group performance (e.g., Gersick & Hackman, 1990; Gigone & Hastie, 1997; Hackman, 1990, 1998). We argue that process mapping facilitates communication among team members and leads to more effective scanning of the problem environment, ensuring that all elements are accounted for and properly addressed, facilitating the problem conceptualization process. Further, we show how components from the more standard definitions of shared mental models (e.g., team roles) fit well within the context of shared models for problem-solving teams.

Problem Structure

The development of a process map represents the development of an organized means with which to conceptualize work flow. As all team members contribute to the map with their unique knowledge base, a detailed representation develops. Specifically, process mapping helps team members flesh out a typically limited understanding of the process in question. While individual team members may possess fairly well-developed knowledge structures with respect to their aspect of a given process, their overall knowledge is, at best, incomplete and, at worst, inaccurate. For example, after process mapping sessions, problem-solving team members have noted, "most people think that they know the whole picture of what goes on in the company . . . After [cross-functional process mapping], you realize that there is a lot more to it than you thought" (Loew & Hurley, 1995, p. 58). Thus, the joint development of the map allows team members the opportunity to elaborate on their understanding of the entire process.

This aspect of process mapping makes it an ideal intervention for overcoming problems due to a tendency for teams to focus more on solution generation than problem conceptualization. In certain situations management may actually encourage this tendency; that is, management may desire solutions to their problems be identified by the team rather than a better understanding of the problem (e.g., Anjard, 1996). But, by focusing the team on the process and the problems inherent in the process (i.e., the disconnects), process mapping teams are forced to forgo discussion of solutions. Thus, we suggest that, in the collaborative construction of the map, participants are required to explicitly define the problem, ensuring that all members are conceptualizing the same problem.

In sum, process mapping provides an enabling structure that allows the team to capitalize on multiple inputs (see Hackman, 1990, 1998). Process mapping creates an environment in which a diverse team can share their knowledge in a way that promotes performance and teamwork. This is particularly important in the context of problem-solving teams because such teams are often ad hoc and will benefit from a structure that scaffolds their communication as they construct their maps.

Team Member Roles and Skills

As the team engages in the initial phases of process mapping, the unique contribution of each individual to the process is made explicit as the map is developed. Specifically, a fundamental purpose of process mapping is to introduce team members to the roles and responsibilities of those involved in a process. Because teams often have the inability to realize who has the knowledge that is most relevant to the problem at hand and how to communicate what is important about the problem (e.g., Serfaty, Entin, & Johnston, 1998), this represents a critically effective aspect of process mapping. Research from studies in the identification of expertise (e.g., Bottger, 1984) shows that groups often fail to determine members of the group who possess critical task knowledge and skills. For example, when interacting teams successfully identified members possessing the most task-relevant expertise, they performed at or near their full potential (Libby, Trotman, & Zimmer, 1987). Nonetheless, many studies illustrate the surprising inability of groups to identify those members possessing the most expertise (e.g., Bottger, 1984; Yetton & Bottger, 1982). Furthermore, organizations too often suffer from a limited understanding of the idiosyncratic skills of employees in differing departments. With process mapping, as the cross-functional team articulates the steps in the process, they are forced to identify which department (and corresponding team member) is involved in that step. This makes explicit not only the capabilities of each team member but also their responsibilities for a given stage in the process.

Process mapping is additionally beneficial because it facilitates information sharing by guiding the transfer of information that takes place during group discussion. A number of studies suggest that group members are more likely to discuss the information they hold in common (i.e., transfer similar data) and not the information they hold that is unique (e.g., Hollingshead, 1996; Stasser et al., 1995; Straus, 1996). Indeed, much research demonstrates that "pooling diverse sets of data via face-to-face discussion [is] more difficult than it seems on casual reflection" (Wittenbaum & Stasser, 1996, p. 6). By means of process mapping, not only do team members pool their resources, that is, contribute their idiosyncratic knowledge, but they also are intimately aware of each other's resources. Thus, with an increase in information sharing, the likelihood of synergistic effects improves as unique information may be brought to bear.

In sum, with process mapping the team is better able to adequately sample items for discussion, particularly when such items are not evenly distributed across the team. For example, after process mapping sessions, problem-solving team members have noted that the initial mapping stages provide "team members a far better understanding of . . . each person's role within the process. This leads to respect and often breaks down barriers that exist departmentally" (Loew & Hurley, 1995, p. 58). This identification of personnel and departmental roles along each step of the process allows team members the opportunity to appropriately acknowledge roles and skills.

Shared Problem Understanding

Overall, this collaborative construction of the process map requires that participants explicitly define their understanding of the process and associated problems, thus facilitating problem conceptualization. This is analogous to what shared mental model theorists have described as *emergent cognition* (e.g., Carley, 1997), or the notion that only as one articulates one's understanding or awareness of a given process does it truly become known to oneself and to others. Thus, the act of making knowledge explicit facilitates the development of not only one's own mental model but also a shared mental model.

More importantly, process mapping forces the team to explicitly negotiate their shared understanding of the process, a step argued to be critical for truly shared mental models (Levine et al., 1993). Others have similarly argued that problem conceptualization at the level of the team only becomes a reality when there is a shared awareness that the group accurately perceives the problem (Larson & Christensen, 1993). For example, after process mapping sessions, problem-solving team members have noted that "the 'as is' map aligns the whole group. It allows you to look at the overall picture of where you've been" (Loew & Hurley, 1995, p. 57). Only after the team agrees on the constructed "as is" map will they move to creating the idealized map, that is, begin solution generation (Mason, 1997).

Last, because a process map is an external representation, it is a concrete manifestation of the team's conceptualization of the problem. Research in collaborative problem solving has demonstrated the substantial benefit of external representation aids. Such studies use augmented displays that allow collaborators to visually articulate abstract concepts and manipulate these task artifacts as the problem-solving process proceeds (e.g., Miller, Price, Entin, Rubineau, & Elliott, 2001; Suthers, 1998). Representation tools, then, are useful because they provide a visual baseline, using a "near universal language," and are thus understandable across departments (Mason, 1997). Illustrating the effectiveness of such aids, process mapping proponents note that the map becomes a key element in team problem solving "because it is visual and people everywhere understand it. Several people in a room can look at the picture or process map and that spurs questions" (Mason, 1997, p. 67). Essentially, process maps illustrate the manner in which team task inputs and team member roles lead to process outcomes (Anjard, 1996). Thus, representational aids for the task at hand can act as a scaffolding with which the team can construct a truly shared, and concrete, depiction of the process problem.

IMPLICATIONS FOR TEAM EFFECTIVENESS

Teams will continue to be a dominant force in organizations, and, as the demand for rapid response to global changes continues to rise, so to will the use of problem-solving teams. In this chapter we suggested that problem-solving teams benefit from the development of shared problem models in a manner similar to teams in more dynamic environments (e.g., Entin & Serfaty, 1999; Serfaty et al., 1998). We identified several distinct problem-solving stages from the cognitive science literature and argued that process mapping facilitates team problem solving by assisting teams in developing a shared conceptualization of the problem. Further, we showed how more standard components of shared mental models actually fit well within the context of shared problem models.

We should note that our approach to shared mental model theory is somewhat unique. Essentially, we suggest that process mapping facilitates a form of team cognition whereby a shared problem model is developed as the team is forced to negotiate the construction of the map. Other approaches, for example, empirical studies assessing mental models, use methods such as concept mapping to assess underlying dimensions of mental models (e.g., Rentsch, Heffner, & Duffy, 1994) or train shared knowledge to facilitate team interaction (e.g., Blickensderfer et al., 1998; Smith-Jentsch, Zeisig, Acton, & McPherson, 1998). Thus, rather than attempting to assess a mental model and make a claim for its existence, we suggest that the map is the model (Jonassen, Beissner, & Yacci, 1993); that is, a process map is an external representation that depicts the shared problem model for a problem-solving team.

Essentially process mapping facilitates the aspect of initial problem solving cognitive scientists have labeled the *search phase* (e.g., Klahr & Dunbar, 1988). In the search phase, the problem solver scans the environment ensuring that all elements are accounted for and addressed. We defined this as the problem conceptualization stage, or the stage that occurs after a problem has been recognized but prior to attempts at generating solutions. Process mapping is beneficial because an adequate initial search phase can help overcome later attempts at solution generation. Process mapping forces the team to recognize deficiencies (disconnects in the "as is" map) prior to attempting to address solutions with the "should be" map. By forcing the team to make a full evaluation of the problem before any suggestions are made, all relevant elements/variables and their interactions are addressed.

By diagramming the entire flow such that interconnections are clear and all repercussions are noted, process mapping provides a means with which to accurately articulate complicated processes and can overcome limitations normally experienced when teams deal with complex problems. The issue of the accuracy versus sharedness of mental models continues to be researched (e.g., Marks et al., 2000; Mathieu et al., 2000; Mohammed & Dumville, 2001), and by providing a means with which to integrate multiple perspectives, process mapping may lead to an accurate shared problem conceptualization. Thus, because process mapping encourages a thorough investigation of the problem space, it may lead to more accurate models of the problem.

Last, we also note the implications of the process map for later problem-solving stages. After a team successfully conceptualizes the problem, they then move to solution generation. In process mapping this entails creating the idealized map (i.e., the "should be" map). The problem-solving team is tasked to "work on isolating and eliminating the irrationalities and redundancies that have crept into the process, attacking the most glaring sources of waste and error first" (Mason, 1997, p. 60). Thus, just as noted by shared mental model theorists (Klimoski & Mohammed, 1994), accurate shared representations of the problem are also important in the later problem-solving stages. Only when problem elements have been identified, properly conceptualized, and agreed on can problem solving proceed effectively.

Some caveats to note concerning the use of process maps include the time required for process mapping. Depending on the complexity of the issue, process mapping can take anywhere from one to several days. But a crucial benefit of process mapping is that no real training is required; the procedure can be learned relatively easily, often in less than a day (e.g., Selander & Cross, 1999). Nonetheless, it may require a skilled group leader or facilitator if the team is inexperienced in the technique. Thus, as in early research on group interaction, in which leaders or facilitators have been documented to benefit group problem solving (e.g., Fiedler, Chemers, & Mahar, 1976; Maier, 1967), process mapping requires such direction (see also Gregory & Romm, 2001). Indeed, as we have argued with respect to process maps, others note that leaders or facilitators are effective when they direct interventions that prompt group members to examine their current problem-solving processes (Gersick & Hackman, 1990; Maier, 1967; Oxley, Dzindolet, & Paulus, 1996), that is, focus on conceptualizing the problem or their approach, *not* the solution.

CONCLUSIONS

The success of process mapping in overcoming interaction problems suggests that there are tools in existence, or tools to be developed, that can begin to truly take advantage of team resources. Heretofore, teams have typically been operating in an additive fashion whereby collective efforts are merely the sum of individual efforts. The question then becomes, what are other tools that are consistently applied in organizations (e.g., cause-and-effect diagrams; Pfadt, 1999), and are they successfully addressing problems experienced by problem-solving teams?

Although the focus of this chapter has been in decomposing the factors that lead to effective team problem solving by means of process mapping, there are two outcomes to be taken from this analysis. The first outcome concerns the research community and how it is that similar analyses can foster a better understanding of the potential causes of performance outcomes when analyzing team cognition. In particular, a closer examination of the many tools in use in industry (e.g., Ishikawa, 1985) is warranted if we are truly going to contribute to a better understanding of organizational interventions. By deconstructing the procedures associated with such tools and identifying their relation to empirically validated performance constructs, researchers may be able to suggest either improvements to existing tools or innovations that provide entirely new approaches to team interaction. Specifically, it is unlikely that such tools would have proliferated had they not demonstrated some measurable success. Therefore, our point is that it behooves us to better analyze current tools to understand what drives their success and limit what may be partial failings. The second outcome concerns the organizational community and how it can benefit from such analyses. Organizational practitioners, who should encourage constructive assessment of these tools, will benefit from an understanding of how they work and when they are best applied.

We conclude that the challenge facing organizational and cognitive psychologists is to fully address the often overlooked difficulties associated with team problem solving and suggest that much needs to be done if we are to truly realize the synergistic potential involved in teamwork. In addition to designing theoretically derived methods for overcoming team processes hindering effective performance, researchers should also more fully analyze the many problem-solving tools being applied to identify their strengths and weaknesses. With a more systematic approach, we can maximize the utility of organizational interventions by more fully delineating the situations for which they are most beneficial.

REFERENCES

Aldowaisan, T. A., & Gaafar, L. K. (1999). Business process reengineering: An approach for process mapping. *Omega: The International Journal of Management Science, 27*, 515–524.

Anjard, R. P. (1996). Process mapping: One of three, new, special quality tools for management, quality and all other professionals. *Microelectronics and Reliability, 36*, 223–225.

Blickensderfer, E., Cannon-Bowers, J. A., & Salas, E. (1998). Cross training and team performance. In J. A. Cannon-Bowers & E. Salas (Eds.), *Making decisions under stress: Implications for individual and team training* (pp. 299–311). Washington, DC: American Psychological Association.

Bottger, P. C. (1984). Expertise and air time as bases of actual and perceived influence in problem-solving groups. *Journal of Applied Psychology, 69*, 214–221.

Cannon-Bowers, J. A., Oser, R., & Flanagan, D. L. (1998). Work teams in industry: A selected review and proposed framework. In J. A. Cannon-Bowers & E. Salas (Eds.), *Making decisions under stress: Implications for individual and team training* (pp. 329–354). Washington, DC: American Psychological Association.

Cannon-Bowers, J. A., & Salas, E. (1990, April). *Cognitive psychology and team training: Shared mental models in complex systems.* Paper presented at the annual meeting of the Society for Industrial and Organizational Psychology, Miami, FL.

Cannon-Bowers, J. A., Salas, E., & Converse, S. (1993). Shared mental models in expert team decision making. In N. J. Castellan, Jr. (Ed.), *Current issues in individual and group decision making* (pp. 221–246). Hillsdale, NJ: Erlbaum.

Carley, K. M. (1997). Extracting team mental models through textual analysis. *Journal of Organizational Behavior, 18*, 533–558.

Chi, M. T. H., Glaser, R., & Rees, E. (1982). Expertise in problem solving. In R. J. Sternberg (Ed.), *Advances in the psychology of human intelligence* (pp. 7–75). Hillsdale, NJ: Erlbaum.

Cowan, D. A. (1986). Developing a process model of problem recognition. *Academy of Management Review, 11*, 763–776.

Entin, E. E., & Serfaty, D. (1999). Adaptive team coordination. *Human Factors, 41*, 312–325.

Fiedler, F. E., Chemers, M. M., & Mahar, L. (1976). *Improving leadership effectiveness: The leader match concept*. New York: Wiley.

Fiore, S. M. (2000). *Problem space and problem solving failure: Cognitive mechanisms in the explanation of process loss in group problem solving*. Unpublished doctoral dissertation, University of Pittsburgh.

Fiore, S. M., Salas, E., & Cannon-Bowers, J. A. (2001). Group dynamics and shared mental model development. In M. London (Ed.), *How people evaluate others in organizations: Person perception and interpersonal judgment in industrial/organizational psychology* (pp. 309–336). Mahwah, NJ: Erlbaum.

Fiore, S. M., & Schooler, J. W. (2001). Convergent or divergent problem space search: The effect of problem structure on group versus individual problem solving. In *Proceedings of the 45th Annual Meeting of the Human Factors and Ergonomic Society* (pp. 483–487). Santa Monica, CA: Human Factors and Ergonomics Society.

Fleishman, E. A., & Zaccaro, S. J. (1992). Toward a taxonomy of team performance functions. In R. W. Swezey & E. Salas (Eds.), *Teams: Their training and performance* (pp. 31–56). Norwood, NJ: Ablex.

Gersick, C., & Hackman, J. R. (1990). Habitual routines in task-performing groups. *Organizational Behavior and Human Decision Processes, 47*, 65–97.

Gigone, D., & Hastie, R. (1997). Proper analysis in the accuracy of group judgments. *Psychological Bulletin, 121*, 149–167.

Glaser, R., & Bassok, M. (1989). Learning theory and the study of instruction. *Annual Review of Psychology, 40*, 631–666.

Gregory, W. J., & Romm, W. J. (2001). Critical facilitation: Learning through intervention in group process. *Management Learning, 32*, 453–467.

Guzzo, R. A., & Salas, E. (Eds.). (1995). *Team effectiveness and decision making in organizations*. San Francisco: Jossey-Bass.

Hackman, J. R. (1990). *Groups that work (and those that don't): Creating conditions for effective teamwork*. San Francisco: Jossey-Bass.

Hackman, J. R. (1998). Why teams don't work. In R. S. Tindale (Ed.), *Theory and research on small groups: Vol. 4. Social psychological applications to social issues* (pp. 245–267). New York: Plenum.

Hackman, J. R., & Morris, C. G. (1975). Group tasks, group interaction process and group performance effectiveness: A review and proposed integration. In L.

Berkowitz (Ed.), *Advances in experimental social psychology* (Vol. 8, pp. 45–99). New York: Academic Press.

Hinsz, V. B., Tindale, R. S., & Vollrath, D. A. (1997). The emerging conceptualization of groups as information processors. *Psychological Bulletin, 121*, 43–64.

Hollingshead, A. B. (1996). Information suppression and status persistence in group decision making: The effects of communication media. *Human Communication Research, 23*, 193–219.

Ishikawa, K (1985). *Guide to quality control.* Tokyo: Asian Productivity Organization.

Janis, I. L. (1972). *Victims of groupthink: A psychological study of foreign-policy decisions and fiascoes*. Boston: Houghton Mifflin.

Johnson-Laird, P. N. (1983). *Mental models: Towards a cognitive science of language, inference, and consciousness.* Cambridge, MA: Harvard University Press.

Jonassen, D. H., Beissner, K., & Yacci, M. (1993). *Structural knowledge: Techniques for representing, conveying, and acquiring structural knowledge.* Hillsdale, NJ: Erlbaum.

Katzenbach, J. R., & Smith, D. K. (1993). *The wisdom of teams: Creating the high performance organization.* Boston: Harvard Business School Press.

Klahr, D., & Dunbar, K. (1988). Dual space search during scientific reasoning. *Cognitive Science, 12*, 1–48.

Klahr, D., Fay, A. L., & Dunbar, K. (1993). Heuristics for scientific experimentation: A developmental study. *Cognitive Psychology, 25*, 111–146.

Klein, G. (1993). A recognition primed decision (RPD) model of rapid decision making. In G. Klein, J. Orasanu, R. Calderwood, & C. Zsambok (Eds.), *Decision making in action* (pp. 138–147). Norwood, NJ: Ablex.

Klein, G., & Pierce, L. G. (2001). Adaptive teams. In *Proceedings of the 6th ICCRTS Collaboration in the Information Age Track 4: C2 decision-making and cognitive analysis*. Retrieved on October 30, 2002 from http://www.dodccrp.org/6thICCRTS/

Klein, G., Pliske, R. M., Crandall, B., & Woods, D. (1999). Features of problem detection. In *Proceedings of the 43rd Annual Meeting of the Human Factors and Ergonomics Society* (pp. 133–137). Santa Monica, CA: Human Factors and Ergonomics Society.

Klimoski, R., & Mohammed, S. (1994). Team mental model: Construct or metaphor? *Journal of Management, 20*, 403–437.

Larson, J. R., & Christensen, C. (1993). Groups as problem-solving units: Toward a new meaning of social cognition. *British Journal of Social Psychology, 32*, 5–30.

Levine, J. M., Resnick, L. B., & Higgins, E. T. (1993). Social foundations of cognition. *Annual Review of Psychology, 44*, 585–612.

Liang, D. W., Moreland, R. L., & Argote, L. (1995). Group versus individual training and group performance: The mediating role of transactive memory. *Personality and Social Psychology Bulletin, 21*, 384–393.

Libby, R., Trotman, K. T., & Zimmer, I. (1987). Member variation, recognition of expertise, and group performance. *Journal of Applied Psychology, 72*, 81–87.

Loew, C., & Hurley, H. (1995). Faster product/process development through cross functional process mapping. *Production, 107*, 56–61.

Maier, N. R. F. (1967). Assets and liabilities in group problem solving: The need for an integrative function. *Psychological Review, 74*, 239–249.

Marks, M. A., Zaccaro, S. J., & Mathieu, J. E. (2000). Performance implications of leader briefings and team-interaction training for team adaptation to novel environments. *Journal of Applied Psychology, 85*, 971–986.

Mason, F. (1997). Mapping a better process. *Manufacturing Engineering, 118*, 58–68.

Mathieu, J. E., Heffner, T. S., Goodwin, G. F., Salas, E., & Cannon-Bowers, J. A. (2000). The influence of shared mental models on team process and performance. *Journal of Applied Psychology, 85*, 273–283.

Miller, D., Price, J. M., Entin, E., Rubineau, B.. & Elliott, L. (2001). Does planning using groupware foster coordinated team performance. In *Proceedings of the 45th Annual Meeting of the Human Factors and Ergonomic Society* (pp. 390–394). Santa Monica, CA: Human Factors and Ergonomics Society.

Mohammed, S., & Dumville, B. C. (2001). Team mental models in a team knowledge framework: Expanding theory and measurement across disciplinary boundaries. *Journal of Organizational Behavior, 22*, 89–106.

Moreland, R. L., & Argote, L. (2003). Transactive memory in dynamic organizations. In R. Peterson & E. Mannix (Eds.), *Understanding the dynamic organization* (pp. 135–162). Mahwah, NJ: Erlbaum.

Moreland, R. L., & Levine, J. M. (1992). Problem identification by groups. In S. Worchel, W. Wood, & J. A. Simpson (Eds.), *Group processes and productivity* (pp. 17–47). Newbury Park, CA: Sage.

Moreland, R. L., Levine, J. M., & Wingert, M. L. (1996). Creating the ideal group: Composition effects at work. In E. H. Witte & J. H. Davis (Eds.), *Understanding group behavior: Vol. 2. Small group processes and interpersonal relations* (pp. 11–35). Mahwah, NJ: Erlbaum.

Moreland, R. L., & Myaskovsky, L. (2000). Explaining the performance benefits of group training: Transactive memory or improved communication? *Organizational Behavior and Human Decision Processes, 82*, 117–133.

Newell, A., & Simon, H. A. (1972). *Human problem solving*. Englewood Cliffs, NJ: Prentice-Hall.

Orasanu, J. (1994). Shared problem models and flight crew performance. In N. Johnston, N. McDonald, & R. Fuller (Eds.), *Aviation psychology in practice* (pp. 255–285). Brookfield, VT: Ashgate.

Orasanu, J., & Salas, E. (1993). Team decision making in complex environments. In G. Klein, J. Orasanu, R. Calderwood, & C. E. Zsambok (Eds.), *Decision making in action: Models and methods* (pp. 327–345). Norwood, NJ: Ablex.

Oxley, N. L., Dzindolet, M. T., & Paulus, P. B. (1996). The effects of facilitators on the performance of brainstorming groups. *Journal of Social Behavior and Personality, 11*, 633–646.

Pfadt, A. (1999). Using control charts to analyze baseline stability: An illustrative example with "real time" data. *Journal of Organizational Behavior Management, 18*, 53–60.

Rentsch, J. R., Heffner, T. S., & Duffy, L. T. (1994). What you know is what you get from experience: Team experience related to teamwork schemas. *Group and Organization Management, 19,* 450–474.

Resnick, L. (1991). Shared cognition: Thinking as a social practice. In L. B. Resnick, J. M. Levine, & S. D. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 1–20). Washington, DC: American Psychological Association.

Rouse, W. B. (1989). *Advances in man-machine systems research* (Vol. 5). Greenwich, CT: JAI Press.

Rummler, G. A., & Brache, A. P. (1995). *Improving performance: How to manage the white space on the organization chart* (2nd ed.). San Francisco: Jossey-Bass.

Salas, E., Dickinson, T. L., Converse, S. A., & Tannenbaum, S. I. (1992). Toward an understanding of team performance and training. In R. W. Swezey & E. Salas (Eds.), *Teams: Their training and performance* (pp. 3–29). Norwood, NJ: Ablex.

Schooler, J. W., Fallshore, M., & Fiore, S. M. (1995). Putting insight into perspective. In R. J. Sternberg & J. E. Davidson (Eds.), *The nature of insight* (pp. 559–587). Cambridge, MA: MIT Press.

Selander, J. P., & Cross, K. F. (1999). Process redesign: Is it worth it? *Management Accounting, 80,* 40–45.

Serfaty, D., Entin, E., & Johnston, J. H. (1998). Team adaptation and coordination training. In. J. A. Cannon-Bowers & E. Salas (Eds.), *Making decisions under stress: Implications for individual and team training* (pp. 221–245). Washington, DC: American Psychological Association.

Simon, H. A., & Lea, G. (1974). Problem solving and rule induction: A unified view. In L. Gregg (Ed.), *Knowledge and cognition* (pp. 105–128). Hillsdale, NJ: Erlbaum.

Smith-Jentsch, K. A., Campbell, G. E., Milanovich, D. M., & Reynolds, A. M. (2001). Measuring teamwork mental models to support training needs assessment, development, and evaluation: Two empirical studies [Special issue]. *Journal of Organizational Behavior, 22,* 179–194.

Smith-Jentsch, K. A., Zeisig, R. L., Acton, B., & McPherson, J. A. (1998). Team dimensional training. In J. A. Cannon-Bowers & E. Salas (Eds.), *Making decisions under stress: Implications for individual and team training* (pp. 271–297). Washington, DC: American Psychological Association.

Stasser, G., Stewart, D. D., & Wittenbaum, G. M. (1995). Expert roles and information exchange during discussion: The importance of knowing who knows what. *Journal of Experimental Social Psychology, 31,* 244–265.

Stout, R. J., Cannon-Bowers, J. A., & Salas, E. (1996). The role of shared mental models in developing team situational awareness: Implications for training. *Training Research Journal, 2,* 85–116.

Straus, S. G. (1996). Getting a clue: The effects of communication media and information distribution on participation and performance in computer-mediated and face-to-face groups. *Small Group Research, 27,* 115–142.

Sundstrom, E., de Meuse, K. P., & Futrell, D. (1990). Work teams: Applications and effectiveness. *American Psychologist, 45,* 120–133.

Suthers, D. (1998, April). *Representations for scaffolding collaborative inquiry on ill-structured problems.* Paper presented at the American Educational Research Association annual meeting, San Diego, CA.

Symons, R. T., & Jacobs, R. A. (1997). Multi-level process mapping: A tool for cross-functional quality analysis. *Production and Inventory Management Journal, 38,* 71–75.

Tanskanen, T., Buhanist, P., & Kostama, H. (1998). Exploring the diversity of teams. *International Journal of Production Economics, 56–57,* 611–619.

Volpe, C. E., Cannon-Bowers, J. A., Salas, E., & Spector, P. E. (1996). The impact of cross-training on team functioning: An empirical investigation. *Human Factors, 38,* 87–100.

Wittenbaum, G. M., & Stasser, G. (1996). Management of information in small groups. In J. L. Nye & A. M. Brower (Eds.), *What's social about social cognition? Research on socially shared cognition in small groups* (pp. 3–28). Thousand Oaks, CA: Sage.

Wittenbaum, G. M., Stasser, G., & Merry, C. J. (1996). Tacit coordination in anticipation of small group task completion. *Journal of Experimental Social Psychology, 32,* 129–152.

Wittenbaum, G. M., Vaughan, S. I., & Stasser, G. (1998). Coordination in task-performing groups. In R. S. Tindale & L. Heath (Eds.), *Theory and research on small groups: Vol. 4. Social psychological applications to social issues* (pp. 177–204). New York: Plenum.

Yetton, P. W., & Bottger, P. C. (1982). Individual versus group problem solving: An empirical test of a best-member strategy. *Organizational Behavior and Human Decision Processes, 29,* 307–321.