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Improving team decision-making performance with collaborative modeling

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Abstract

Purpose – This article aims to examine considerations and strategies for improving team performance in decision-making by teaching teams to use collaborative modeling based on team mental models.

Design/methodology/approach – The article describes the nature of shared mental models and collaborative modeling, the potential effects of collaborative modeling on team performance, and a perspective on communication imperatives that facilitate collaborative modeling. The articles builds upon this information to suggest five imperatives for teams to help them develop collaborative modeling skills

Findings – The article offers strategies in the form of five imperatives for teams to observe in order to build skills in collaborative modeling and improve team performance by improving team members' ability to effect collaborative modeling to accomplish team tasks and goals.

Originality/value – Research over the years in mental modeling and communication has created a powerful argument that effective communication and shared mental models improves team performance. However there is little about application of this concept in the literature. The next step for researchers is to develop application models for collaborative modeling and test those models through empirical research. This paper offers an application model based on imperatives to be observed by decision-making teams in order to facilitate the creation of shared mental models of team tasks and processes.

Keywords Team performance, Decision making, Modelling

Paper type Conceptual paper



Introduction

The idea of mental modeling and shared mental models is used increasingly to describe team decision-making processes. Theorists believe teams use shared mental models to develop a common knowledge of such things as team objectives, decision structure, solution alternatives, information requirements, team tasks, processes and procedures, and roles and functions of other team members. For example, some researchers (Blickensderfer *et al.*, 1997; Cannon-Bowers and Salas, 1997) have suggested that team decision-making performance is contingent upon how well team members can construct and share mental models about the decision structure representation, relationships of the decision variables, and outcome expectancies. From the mental modeling perspective we can describe team functioning in terms of team members'

sharing individually held mental models with other team members and also working collaboratively with other team members to create shared mental models.

The term collaborative modeling as used in this paper does not represent a new concept but represents an aspect of the concept of shared or team mental models implied, but not fully articulated, in the literature. In this paper we will examine collaborative modeling in the context of improving team decision-making performance and offer five imperatives for successful team collaboration.

In team decision-making situations, team members possess different levels of experience and knowledge needed for the collective task at hand. Even if team members have some experience and knowledge in common, they will process information differently (Mohammed *et al.*, 2000). They also have different cognitive processing schemes. They can share this experience and knowledge with other team members as the team pursues its objective and performs the required tasks to reach a decision. In some cases, a more experienced or knowledgeable team member may already possess the necessary models the team needs to accomplish its mission. When this occurs, the team only needs to develop the appropriate shared mental models based on the experienced team member's model and employ the shared model to accomplish the required tasks. Collaborative mental modeling, on the other hand, occurs when the team members possess no relevant models and are faced with the task of working together to create and share a new model.

There are several questions that need to be answered in order to fully understand collaborative mental modeling. How does collaborative mental modeling work? What are the requirements for collaborative modeling? What variables in the context of decision-making teams affect collaborative modeling? What are some considerations for successful collaborative modeling?

Collaborative mental modeling is a process by which team members work together to create new shared mental models. In this case, individual models do not exist or are inadequate for the purpose of sharing with other team members. Two principle component concepts of the collaborative modeling process are shared mental modeling and team communications. To understand how this process works, we need to first examine the characteristics of shared mental models, which are the product of the collaborative modeling process. Next, we need to describe a communications model that supports collaborative mental modeling, including the affecting variables and their influence on decision-making teams. Finally, we need to articulate the "mechanics" of the collaborative mental modeling process that produces new shared mental models for the decision-making team.

Mental models and shared mental models

In contemporary literature cognitive modeling has been variously described in the context of knowledge structures called schema (Gagne and Glaser, 1987; Mayer, 1992; Rentsch and Hall, 1994), cognitive maps (Eden, 1992), and mental models (Craik, 1967; Johnson-Laird, 1983). Mental modeling and shared mental modeling are terms most commonly used in the literature today to describe cognitive modeling.

Mental models

In recent literature, one of the most frequently cited definitions of mental models comes from Rouse and Morris (1986, p. 360): "Mental models are the mechanisms whereby

humans generate descriptions of system purpose and form, explanations of system functioning and observed system states, and prediction of future system states.” Another popular definition of mental models is: “Mental models explain human cognitive processes of understanding reality, translating reality into internal representations and utilizing it in problem solving” (Park and Gittleman, 1995, p. 303). Glaser and Bassok point out that mental models are “runnable” mental simulations that are built, used, and modified as proficiency is acquired (Glaser and Bassok, 1989). These descriptions also suggest that mental models may provide a paradigmatic cognitive processing function in that mental models may be used as a processing “blueprint” to guide individuals through new situations.

Shared mental models

Shared (or team) mental models are cognitive representations or structures of the task, situation, and context that are held in common by team members. Shared mental models help team members formulate collective explanations and expectations of the task, share of problem representation and orientation, facilitate communication and coordination of team activities, and help the team develop and sustain situational awareness (Cannon-Bowers and Salas, 1997; Kraiger and Wenzel, 1997; Salas *et al.*, 1993; Stout *et al.*, 1996).

From this definition we see that shared mental models are knowledge structures held in common by a group and facilitate communication of task requirements and goals in the collective problem-solving process. This is an important concept in the context of collective problem solving and team building. If team members working on a problem are not on the same cognitive “sheet of music” with respect to the required tasks, conditions and completion success criteria, they will have difficulty in moving towards a solution.

Characteristics of shared mental models. We can use systems models to classify types of shared mental models in team situations based on types of knowledge (“what, why, and how”) (Rouse *et al.*, 1992). Simply stated, they suggested that team members should have knowledge of any combination of what the system was doing, why it was doing it, and how it did it, in order to properly function as a team. Shared mental models should produce a synergistic effect when engaging in collective problem solving or task execution since they enable team members to share or overlap knowledge and, therefore, hasten individual schema processing for the task at hand (Blickensderfer *et al.*, 1997). Because of this enhanced processing, teams making decisions and working against time constraints will benefit from possessing skills for developing shared mental models of the decision structure.

Research has shown that shared mental models can be distributed among team members (Banks and Millward, 2000). Team members can possess different elements of information needed to create a common model, and can work collaboratively to build the common model. This implies that in making team decisions, team members do not need to know all the information concerning a particular decision, but can acquire full knowledge of the decision structure through the development of shared mental models. Collaborative modeling occurs when the team members not only share and integrate their own models and model elements, but add new information associated with a new decision situation to evolve a new shared model.

Researchers have suggested that shared mental models may evolve to a higher efficiency level as the team matures and shares more experiences (Salas and Cannon-Bowers, 1996). The literature also supports the idea that team mental models can evolve over time through a process of progressive convergence or overlap of the models of individual team members (Blickensderfer *et al.*, 1997; Glickman *et al.*, 1987). In a similar vein, mental models are believed to evolve from a novice state to an expert state as an individual or team gains experience and refines the model (Gualtiere *et al.*, 1996; Klimoski and Mohammed, 1994).

Types of shared mental models. Cannon-Bowers *et al.* (1993) proposed an elaboration of the types of shared mental models employed by teams. They hypothesized that teams can share declarative, procedural, and strategic knowledge in the performance of team activities. They further refined this classification by describing shared mental models employed by teams as equipment models, task models, team interaction models and team attribute models (Rouse *et al.*, 1992).

Equipment models pertain to how things (tangible or intangible) function as well as the procedures to make them function and information about the functioning. Task models involve information about the task to be performed, task procedures, likely scenarios, task strategies, and environmental constraints. The team interaction model is the blueprint for how the team works as a team. Finally, the team model contains information about other team members' knowledge, skills, abilities, preferences, and tendencies (Cannon-Bowers *et al.*, 1993).

Teams can use shared mental models to facilitate the development of teamwork and taskwork skills (Cannon-Bowers and Salas, 1997). Researchers have suggested that team members can use shared mental models to develop team members' knowledge, skills, and attitudes required for effective teamwork, and the understanding of facts, concepts, relations, and underlying foundation of information needed to perform tasks (Cannon-Bowers and Salas, 1997). If team members are aware that sharing mental models can improve individual and team performance, then this relationship would be the impetus for training members in how mental models work and how to share them within the team. Other researchers view the team development process as occurring along two dimensions: teamwork (involving relationships, interactions, and cooperation within the team) and taskwork (related to the specific activities to accomplish the task at hand) (Morgan *et al.*, 1993).

Shared mental models may consist of any of three elements: knowledge, behavior, and attitudes (Kraiger and Wenzel, 1997). The knowledge element includes the aspects of how team members perceive, process, or react to external stimuli, as well as how team members organize and structure task-relevant knowledge. The attitudinal element involves the emotive processing and interpretation of the team environment and activities. The behavioral element includes the team members' shared expectations of each other's behavior.

Shared mental models and team performance. Blickensderfer *et al.* (1997), summarized research into the effect of shared knowledge on team performance and concluded that shared knowledge is a necessary condition for team performance. Teams must be able to develop a shared mental model of the team's task, which includes the structure of the task components (Cannon-Bowers and Salas, 1997). Finally, positive relationships between team processes and performance and shared mental modeling have been observed in team simulations (Mathieu *et al.*, 2000).

For a team to make decisions effectively in a dynamic decision environment, team members must collectively understand and communicate the structure of the decision and develop decision alternatives in an interdependent manner. The team must then arrive at a decision that is appropriate for the current situation (Driskell and Salas, 1992; Rouse *et al.*, 1992; Senge, 1990; Stout *et al.*, 1996). This type of situation would require collaborative modeling skills to be in place within the team in order for the team to create new models to address new situations or decisions.

Team mental models help team members formulate collective explanations and expectations of the task, share problem representation and orientation, facilitate communication and coordination of team activities, and help the team develop and sustain situational awareness (Cannon-Bowers and Salas, 1997; Kraiger and Wenzel, 1997; Salas *et al.*, 1993; Stout *et al.*, 1996). Teams that employ collaborative modeling learn each other's knowledge structures that pertain to the tasks and procedures for the team overall. This helps team members to monitor team processes and detect and correct errors or problems more easily. If a team member observes an action or receives information that does not fit the team member's expectations according to the shared model, the team member can generate a feedback response based on the model. Because the team shares the model, the members can more quickly recognize the inconsistency and then identify and correct errors. When team members monitor performance, both team and individual, and provide feedback to other team members, such feedback facilitates corrections and improvements that, in turn, improve performance (Rasker *et al.*, 2000).

Reliance on shared models can lead to problems. For example, if new conditions of the situation dictate model adjustments or additions to the model to accommodate the new situation, and none are made, errors are likely to occur. If a team allows its shared mental models to become out-of-date for the given situation, and yet still relies on those models, a situation called "groupthink" may occur. In this situation, the team model evolves to the point that team members exhibit a type of complacency by becoming reliant on automated, static problem-solving mechanisms previously developed by the team. This causes them to reduce their individual contributions or defer to established team problem-solving processes. Additionally, team members in highly cohesive teams may allow the desire to conform to interfere with their participation or defer to opinions or support decisions they may not fully agree with (Mullen *et al.*, 1994; Mullen *et al.*, 1991; Salas and Cannon-Bowers, 1996). Another limiting factor for collaborative modeling may be participation. If a team attempts to employ collaborative modeling, all members must support it in order to realize the full potential of the team. Collaborative modeling may not be a process agreeable to all members of the group. Finally, some team members may not perform well in collaborative modeling situations or may prefer not to participate in collaborative modeling efforts (Jeffery and Maes, 2002).

It is now apparent that decision-making teams need to develop collaborative modeling skills in order to generate new shared mental models that provide a structure for arriving at decisions for new situations. Underlying the development of shared mental models is the effective communication of individual models and sharing of perspectives and ideas that address the new decision situation. Research indicates that teams that use efficient communication strategies and techniques achieve higher levels of decision making performance (Stout *et al.*, 1999).

Communication and collaborative mental modeling

As previously established, shared mental models facilitate communication and at the same time depend on effective communication among team members. When a team making a decision is faced with a new situation, the members can call on existing shared mental models to support a new decision. Alternatively, if existing models are inadequate, they can be extended or modified to fit the new situation. Finally, new models can be created to support the decision. In all cases, there must be effective communication among team members to facilitate fast development of shared mental models in order to improve the team's decision-making performance.

We can consider teams as micro-organizations that can be viewed in light of systems theory. This approach, as it relates to organization communication, is used because teams, like organizations, are living organisms or open systems—that is, those that have input, throughput, and output (Bertalanffy, 1968; Waters, 2002). Like a living organism, the organizational system processes information and grows, maintains, or dies, depending on how well it adjusts to and meets the challenges presented by its environment (Weick, 1979; Miller, 1999; Waters, 2002). Teams making decisions are constantly faced with new situations in their environment and achieve success depending on how fast they can “cycle.” The research presented so far supports the argument that efficient collaborative modeling supported by effective communication will result in improved performance.

Researchers have identified five key components of organizational communication: environment, enactment, equivocality, assembly rules and communication cycles, and causal maps (Miller 1999; Waters, 2002). From a systems perspective, communication within an organization (or a team) is ever-changing and is influenced by those existing in it.

The environment is something that confronts team members, and, is simultaneously being affected by how team members react to or act upon it. Taken one step further, each individual team member projects his/her own perceptions, interests, motivations, personalities, and experiences onto the environment. This is referred to as enactment. Since individuals view their environment differently, they interpret information differently. In team decision-making, collaborative modeling is a way for individuals to share their different perceptions of the decision environment in order to forge a common definition of the decision elements and structure.

Equivocality is the unpredictability within the informational environment of an organization or team. Equivocal information can be interpreted in a variety of ways. The process of organizing can be seen as the process of making sense of organization equivocality or unpredictability (Weick, 1979). So, organizing is a sense-making process, and in a team context, must be a collaborative effort.

Teams making decisions use assembly rules and communication cycles for sense-making. In situations where equivocality is fairly low (highly predictable circumstances or routine decision-making situations), assembly rules provide a recipe for dealing with and interpreting the environment. Such mechanisms relate directly to collaborative modeling that extends or modifies existing shared mental models and are a key ingredient for facilitating the creation of shared mental models that are used in sense-making and interpreting variations of new situations.

When there is a high degree of uncertainty, however, information is processed through communication cycles. These occur because there is no clear assembly rule for

addressing the situation, or the situation is too complex for the prescribed assembly rule. When the situation dictates the use of communication cycles, team members exchange ideas in an attempt to make sense of a highly equivocal or unpredictable situation. In decision-making processes, collaborative modeling to create new shared mental models that effectively explain the situation would require communication cycling.

Assembly rules and communication cycles are selected based on a team's perception of the equivocality of the environment. Sometimes the selection is effective and others times it is not. When the selected assembly rule or communication cycle is deemed effective, it is then retained or saved as a new model for future team use. In information processing, this new model is called a causal map another form of shared mental models (Eden, 1992). These causal maps or models serve as future guides to sense making.

When circumstances surrounding team tasks or decisions are highly predictable, simple rules and structures already established within the team may suffice. When environments are more variable, team tasks are less clear, or decisions are being made under conditions of uncertainty, more complex communication cycles and systems are needed for sense making. Overall team effectiveness and performance depends on how well the team recognizes and commonly "views" the structure of the task or decision at hand and matches the complexity of its communication structures to the complexity of its environmental challenges. This can be done through the extension or modification of existing models or the creation of new ones. Thus, in collaborative mental modeling for decision-making teams, the communication challenge is to collectively develop effective assembly rules and communication cycles quickly.

Team decision-making performance relies on recognizing the collaborative modeling needed, effective communication, and the success of building shared mental models among team members through collaborative modeling. The next section will develop a process model for collaborative modeling

Imperatives for collaborative mental modeling

Team performance can improve through the application of collaborative modeling to create shared mental models to facilitate accomplishing team tasks and goals. Such collaborative modeling relies on effective communication. In order to improve performance, teams should develop effective communicating and collaborating strategies that result in the creation of shared mental models that help team members perceive a common working framework for the task at hand.

Based on the information presented thus far, a logical set of imperatives for effective collaboration would include:

- *Imperative 1.* Clarification of team objectives and tasks, environment and variables.
- *Imperative 2.* Establishing roles and responsibilities.
- *Imperative 3.* Information processing, communication, and collaborative modeling rules and procedures.
- *Imperative 4.* Knowledge of team members' background and style.
- *Imperative 5.* Collaborative modeling scheme.

This list of requirements is not necessarily a specific sequence or process, but would probably follow the order presented for developing teams. The actual order for these requirements would depend on the nature of the team, the length of time the team has worked together, the degree of familiarity and comfort in working together among team members, the level of experience and expertise of the team and its members, and the extent to which these requirements have already been met.

Imperative 1. Clarification of team objectives and tasks, environment and variables

Perhaps the most fundamental requirement for collaborative modeling is for all team members to clearly understand team objectives (functional and performance) the tasks (teamwork and taskwork) that will be required to accomplish the objectives, the environment the team will be performing in, and variables that will affect team performance. This includes clarification of task models that involve information about the task to be performed, task procedures, likely scenarios, task strategies, and environmental constraints. Also involved is the clarification of equipment models that pertain to how things (tangible or intangible) function as well as the procedures to make them function and information about the functioning (Cannon-Bowers *et al.*, 1993). Formal decision-making procedures would constitute equipment models.

The objectives and tasks need to be clearly defined through a process of group discussion and consensus building. It is critical that each team member hold the same understanding of the objectives and tasks. Team members should understand that this process serves two purposes. First, and obviously, is the requisite understanding of the objectives and tasks. Second, this is often the first opportunity for team members to learn and practice deliberate collaborative modeling and effective communications.

One technique for establishing collaborative modeling as a team objective and task is for the team to address in open discussion the need for collaborative modeling, sharing mental models, developing effective communications mechanisms, and developing techniques for performance monitoring and feedback. The team will then try to translate these needs into team goals. This can be accomplished by a team leader, a facilitator, or a knowledgeable team member. Team members should understand that in addition to clarifying objectives and tasks and identifying collaborative modeling and effective communications as team goals, open and thorough discussion builds understanding of each other and exercises or “warms up” the collaboration and communication process.

Imperative 2. Establishing roles and responsibilities

Clarifying team member roles and responsibilities should be accomplished after the team defines team objectives and the tasks necessary to accomplish the objectives, and sets collaborative modeling and effective communications as team goals. This requires the development of team interaction models that represent a blueprint for how the team works as a team (Cannon-Bowers *et al.*, 1993). A mature team may already have established roles and responsibilities for its team members, but restatement and clarification in light of new team objective and tasks is a good idea. Any additional roles and responsibilities deemed necessary by the team to help in collaborative modeling and communications should be clearly articulated at this time. These new roles and responsibilities can be clarified through open discussion again to exercise the collaborative modeling and communication process.

Imperative 3. Information processing, communication, and collaborative modeling rules and procedures

Once team members are clear on objectives, tasks, roles and responsibilities, they should next address techniques they will use for communicating, feedback, and sharing mental models. These techniques will vary significantly depending on the purpose, composition, and longevity of the team. As a minimum, team members need to learn the fundamentals of collaborative modeling and communication and then be trained on techniques for effectively building shared mental models that will help improve team performance in accomplishing team objectives. Beyond the fundamentals, team members need to discuss and agree on specific techniques they believe will help them communicate and synthesis individual mental models, integrate new information into the collaborative modeling effort, and develop shared mental models for structuring different tasks and decisions processes.

Imperative 4. Knowledge of team members' background and style

When team members know each other well, they communicate better. When team members communicate well, they have a greater opportunity to develop shared mental models that can help improve team performance. Team members should have the opportunity (as much as possible within time and resourced constraints) to participate in self-assessment activities that reveal personality types, learning styles, and communications preferences. When the results of these activities are shared with other team members and interpretations are made in terms of how specific individual differences may impact team mechanics, individual members will gain insights on how to most efficiently communicate, collaborate and use shared mental models. This paves the way for the development of team model that contain information about other team members' knowledge, skills, abilities, preferences, and tendencies (Cannon-Bowers *et al.*, 1993).

Imperative 5. Collaborative modeling scheme

The final aspect of effective collaborative modeling is the collaborative modeling scheme to be used by the team. This is a plan for creating the shared mental models deemed necessary by the team. This plan includes rules and procedures for articulating individual models and the process the team will use to develop a shared mental model. The plan would also identify tools selected by the team such as flow charts, concept maps, cause and effect diagrams, etc. The importance of planning within teams to improve performance is well established in the literature (Stout *et al.*, 1999).

Conclusion

Shared mental models are a key to improved team performance. Teams making decisions need the ability to process new information associated with new situations. Collaborative modeling as presented here would be the process by which decision-making teams would develop evolutionary shared mental models to represent the decision structure needed. By addressing the five prerequisites presented here through team training and team building, decision-making teams will maximize their ability to effectively create collaborative cognitive models for the decision at hand.

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