Comparing the Effects of Conceptualization, Simulation and Facilitation on Mental Model Development in a Group Setting: An Experimental Investigation Utilizing Case Study and Management Flight Simulator Approaches

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ABSTRACT

The practice of building and exploring system dynamics models with groups of non-experts is still relatively new to most organizations. One primary concern in this practice is how to structure group modeling sessions so that participants' mental models of system functioning may be most effectively elicited and made more robust given a limited time frame in which to conduct group-based activities.

This paper is drawn from dissertation research underway at a major southwestern U.S. airline. The study is designed to look at the impact that model conceptualization (via case study), simulation (via management flight simulator) and facilitation of the these processes have on the elaboration and revision of individually held mental models. Included in the discussion is a summary of the background literature on which the study is based, the underlying theoretical model used for establishing the experimental framework, and an overview of methodology being applied.

The Mental Model Construct

Perhaps because of the "broad church" backgrounds of those working in the area of mental models (Wilson & Rutherford, 1989), few formal, widely accepted definitions of the mental model construct exist (Rouse & Morris, 1986). More often mental models are defined according to the field and context in which they are employed. While a relatively new subject of interest in the field of management (e.g. Senge, 1990b), the field of psychology has had a long history of the use of the term mental model. As early as 1943, Kenneth Craik proposed that, "we construct internal models of the environment around us that form the basis from which we reason and predict the outcome of events" (Rogers, 1992, p. 2). His view, as with nearly all others offered since, is that people create symbolic representations that "mirror" external events. Forty years after Craik's writing, the mental models construct was used by cognitive psychologist Johnson-Laird (1983). Drawing on Craik's ideas, Johnson-Laird, suggested that people "understand the world by constructing working models of it in their mind" (p. 10) and use cognitive models as "inference engines" which function recursively to enable the understanding of discourse and allow reasoning through the manipulation of symbols or 'tokens' which are derived from the structure and meaning of speech (Luria, 1973).

Rouse and Morris (1986) propose a functional perspective on mental models defining them as specialized cognitive structures that enable a person to *describe, predict, and explain* the behavior of any given system. For example, in talking about an organizational system, a mental model may be used for such tasks as *describing* the system's purpose and form, for *predicting* how policy changes may affect the system, and for *explaining* why the system functions as it does (Cannon-Bowers et al., 1993; Wickens, 1992). In attempting to describe, predict and explain how a system functions, it is believed that people manifest these internal models as imagery reflecting the spatial layout of that system (Johnson-Laird, 1983; Rasmussen, cited in Wilson & Rutherford, 1989) or as associated concepts in task descriptions (Schvaneveldt, et al., 1985).

Differentiating Mental Models From Knowledge

What is sometimes inferred in discussions regarding mental models is the idea that mental models and knowledge are the same thing. According to Rouse and Morris (1986), this is an erroneous assumption. Mental models differ from knowledge in "how they are organized" (Woods et al., 1994) and in that they have specific "meaning" associated with them (Drath & Palus, 1994), both of which are derived as a function of individually and socially-based experiences (Kelly, 1955). A further delineation between mental models and knowledge in general is that mental models are dynamic or "runnable". That is to say, components of the mental model may be simulated in interaction to predict the outcome of concepts working in concert (Craik, 1943).

Whereas knowledge may be the content or basic elements of mental models, mental models themselves are considered *special* types of knowledge (Rouse & Morris, 1986). Converse and Kahler (1992) distinguish three special types of knowledge: *declarative knowledge, procedural knowledge and strategic knowledge*. Declarative knowledge is knowledge used to relate concepts (single ideas) to one another to show cause and effect. They give insight into the relationships that are presumed to exist between various phenomena. Declarative mental models are also believed to be culture-based so that the meanings of these models may be dependent upon the context in which they are used (Carley and Palmquist, 1992; Drath & Palus, 1994; Woods et al., 1994).

The second type of specialized knowledge is procedural knowledge. Procedural knowledge is episodic, or time-based in nature. It is used to inform a person about how to perform some act or how some sequence of events should occur. Procedural knowledge is explicit in nature but there is typically little behavioral discretion over its use - it becomes semi-automatic (Rassmussen cited in Rouse & Morris, 1986).

The third type of special knowledge described by Converse and Kahler (1992) is strategic in nature. Strategic knowledge is said to be a combination of declarative and procedural knowledge. Mental models made up of strategic knowledge are typically 'expert-based' as they allow for making decisions about when and where to apply procedural or declarative knowledge to reach a specific goal. Strategic knowledge is said to develop over time with practice and is often described using 'chunks' of information or heuristics that are partly based on past experience. Strategic knowledge appears to align most closely with descriptions of a decision maker's mental model of their organizational system. Ultimately, as evidence builds that supports the premise of different types of mental models containing differing content of specialized types of knowledge, different methods for tapping into these various stores of knowledge are called for (e.g. Converse & Kahler, 1992; Gordon, et al., 1993; Huff, 1990).

Mental Model Reliability

In keeping with the idea that mental models are made up of different types of specialized knowledge used to describe, predict and explain system behavior, Forrester (1994) and Senge (1990a) note that people have varying levels of difficulty articulating different aspects of a perceived system accurately. They identify three categories of data that are held in a decision makes possess which appear to correspond closely with the functional definition of mental models proposed by Rouse and Morris (1986) and they assert that there are different levels of reliability associated with each. First, there is data about system structure and policies which are assumptions used to *describe* how variables interact with one another. According to Senge, assumptions about policies and structures can be reported with a fairly high level of consistency. However, assumptions in the second category, those used to *explain* system behavior (changes that have happened or are happening), may be misinformed or erroneous. The third category of data in the mental data base deals with assumptions used to *predict* future system behavior. These models represent detailed information encompassing *both* system description and explanation and represent intuitive solutions people give when asked to predict what will happen when structure and policy interact. As supported by Sterman's studies (1989) on the misperception of feedback, Senge and Forrester contend that these assumptions are *least* reliable as people consistently misjudge the dynamic behavior of how the pieces in a system will interact over time or how behavior would be altered by new policies.

Using System Dynamics in a Group Setting to Aid in Mental Model Development

There has been a growing emphasis on developing tools and processes that help decision makers *learn from models* through the articulation and examination of their own mental models in a group context (Andersen & Richardson, 1997; Lane, 1994; Richardson & Andersen, 1995; Richmond, 1997; Vennix, et al., 1996). Building system dynamics models with groups of people differs in its aims from previous efforts to derive expert-based models. Unlike modeling where the goal is to replicate an actual system as closely as possible, the primary goal in modeling as a means to learning at the group level is not to derive a 'correct' model of the system but rather, focus is placed on the *process* of engaging a group in building a model of a problem in a way that contributes to their understanding of the issues and which may lead to a new course of action to which they feel committed (de Geus, 1988; Vennix, 1996; Vennix, et al., 1996).

To describe how the model building process may alter mental models, Senge (1990a) and Senge and Sterman (1994) describe a recursive process of mental model development involving three stages: mapping mental models, challenging mental models to reveal inconsistencies, and improving mental models. In the first, mapping mental models, their premise is that mental models can not evolve unless they are first made explicit (de Geus, 1988; Forrester, 1975). By having participants talk about the specific variables in a system and answer questions about these variables, they may draw on their domain specific experiences and in the process make their mental models explicit and known to others (Bakken, et al., 1994; Eden, 1989; Narayanan & Fahey, 1990).

In the second stage, challenging mental models, an attempt is made to test individuals' existing mental models for validity by seeking to uncover internal contradictions, inconsistencies, or incompleteness (Senge, 1990a). When people encounter a mismatch between what they expect will happen in a simulated experiment and what actually occurs in a given situation, their response may be a modification of their images, maps and activities in order to bring these expectations and outcomes into line (Argyris and Schön, 1978; Williams, et al., 1983). Only after people have gone public with their mental model, say Senge and Sterman (1994), can they begin to discover inconsistencies and contradictions with other sources of information. Finally, improving mental models through system dynamics modeling involves efforts to revise assumptions when they prove to be erroneous (de Geus, 1988; Senge and Sterman, 1994). The process of revising a mental model does not happen quickly however (Senge, 1990a) as new conceptual perspectives may be assimilated gradually (Levitt and March, 1988) or perhaps not at all if current models, though perhaps simpler, seem to function satisfactorily (Woods et al., 1994).

The Role of Social Interaction in Mental Model Development

It is theorized that applying the system dynamics modeling framework in a group setting enhances the group interaction process and that this interaction in turn, affects the development of members' mental models (Lane, 1994; Morecroft and Sterman, 1994; Vennix, 1996). One basis for this assertion is that mental models may be enriched the longer a person *thinks* about a topic (Morecroft, 1994; Woods et al., 1994). That is to say, when group interaction occurs, people remember more facts and concepts so that their cognitive models may include not only a network of 'familiar' facts and concepts, but a vast matrix of *potential* connections stimulated by the flow of conversation (Forrester, 1975). Observations by Anderson et al. (1992) support this idea. Based on videotapes of an 'interactive protocol' (live exchange between people working on a task) Anderson et al. observed that working with a peer resulted in improvements in subjects' mental models used for prediction, particularly if the individual contrasted their pre-test predictions with those of another person and entered into discussions as to possible explanations of the phenomena.

From a cognitive theory perspective, group interaction may affect mental model development because the process of social interaction allows for the use of two separate but cooperative types of working memory (Wickens, 1992). According to Wickens, one type, spatial working memory, represents objects in visual or spatial form while the second, verbal or phonetic working memory, represents information as words or sounds. During discussion, the relationships between mental model elements tapped by the visual representation may be enhanced because the phonetic working memory resources are utilized as well.

Group interaction may not always improve problem solving performance however as high status persons may dominate discussions so that participation is not equal among group members (Bakken, et al., 1994; Eden, et al., 1983; Hodgson, 1994; Vennix and Gubbels, 1994). Without a neutral third party to inquire into the meaning of statements, ensure that all group members contributions are heard, and mediate opposing views, the group may spend a great deal of time arguing ideas until they eventually tire and defer to the most senior person (Senge, et al., 1994). The delicate balance between effective group interaction and dominance by an individual in a group setting suggests that the role of a neutral outsider to facilitate the group's process is a vital one.

The Role of Facilitator in Fostering Social Interaction

In the arena of group model building, the role of facilitation is considered vital to effective group process because: 1) the facilitator may affect the level of debate that occurs in the group; 2) he or she may mediate the power relationships that emerge in a group interaction and help ensure that the group doesn't narrow their focus to a few approaches to the problem too soon; and 3) he or she may have a positive effect on communication that transfers to other forms of group effectiveness (Akkermans & Vennix, 1997; Morecroft, 1994; Richardson & Andersen, 1995; Senge, et al., 1994; Vennix et al., 1994). First, whether or not alignment of mental models between two or more individuals occurs may be a function of how effective the facilitator of the group process is in fostering group interaction, as "the effectiveness of the learning cycle depends on...the skill which knowledge is elicited and...options and consequences are debated (Morecroft, p. 11). A facilitator may encourage people to scrutinize and justify their reasoning regarding the viability of an idea while helping to side-step argumentation. When the model is used to stimulate debate, the model may be seen as an additional viewpoint which then becomes the focus for the debate rather than individual group members (Eden, 1989; Morecroft, 1984).

Secondly, a facilitator may mediate the power relationships that arise in a group setting in two ways. One, if a model is embedded in a computer-based simulation, the facilitator can establish a context in which the simulation is viewed as a tool for learning that goes beyond a position as an infallible 'black box' to occupy a more modest position as an inanimate *generator of opinions* that decision makers are encouraged to challenge (Morecroft, 1994). And two, whether or not they intend to do so, the facilitator can effect the power relationships present in the team through the selection of what they incorporate in a conceptual model and how (Doyle, et al., 1996; Eden, 1994; Eden, et al., 1983).

Finally, effective facilitation may have a positive impact on the level and type of communication that occurs during the model building process which in turn may have an effect on: 1) the degree of group consensus; 2) ownership of the model and; 3) commitment to the recommendations that result (Akkermans & Vennix, 1997). First, the facilitator's contributions to effective communication may have a positive impact on group consensus. In a study of six group model building interventions, Akkermans and Vennix found that communication during the process was positively related to forming consensus around the nature of an issue. In five of the six cases studied, good communication coincided with fair to high levels of group consensus. They also observed that when people communicated openly and effectively, the group developed a greater feeling of ownership over the resulting model. This, they assert, may contribute to a higher level of commitment to recommendations for policy changes.

How successful the facilitator is in bringing about these effective patterns of behavior however may be a function of how skilled he or she is in tempering the effects of organizational politics and defensive behaviors. When confronting problems that are out of the ordinary and complex, members of a problem solving team may exhibit defensive behaviors such as unwittingly defending prior positions, selecting information and arguments that confirm already established views, attributing error to those whose views differ from their own, and seeking to 'win', rather than learn (Argyris, 1990; Argyris and Schön, 1996; Senge, 1990a). In group interactions, people may become so enmeshed in defensive social behaviors such as face-saving, protectiveness, the appearance of strength and the suppression of feelings of vulnerability that they find it hard to conceive of and act in ways that would support deeper learning (Forrester, 1994; Isaacs and Senge, 1994; Morecroft and Sterman, 1994).

Summary and Implications of the Literature Review

An underlying assumption in the field of system dynamics is that 'systems thinking' can be taught, that is, that people can be made aware of connections and feedback between structure and behavior. If so, then mental models about how the parts of a system interact may be revised so that they become more coherent (Lane, 1994). Unfortunately, possessing a mental model that is more coherent does not necessarily mean that it will be sufficient to handle the cognitive load when trying to accurately predict what will happen when several events and processes interact. Studies have shown that the human brain is not capable of simulating interactions beyond a minimal number of variables. Overcoming this limitation requires mechanisms for freeing up attentional resources - a kind of framework for organizing the data so that it can be stored as 'chunks'. As organizing frameworks, both model conceptualization and model simulation are advocated as effective ways to develop more systemic views of an organizational system. These organizing mechanisms may be useful for filtering knowledge and categorizing it in such a way that the brain's processing resources are freed up for other cognitive tasks such as searching memory for other appropriate data to extend the mental model or for mentally simulating potential interactions between variables. If a simple framework is sufficient to free the cognitive load, this begs the question, would the same 'aha' experience sometimes noted with simulation be possible just as readily with any organizing process since, from a cognitive standpoint, when an individual experiences an insight it may be said that the intervention has somehow "tweaked" the individual's attention to the fact that "something new" has been presented? From a research point of view, it may be said that the more any particular method *challenges* people's thinking, the greater the chances that their mental models will be altered. This is not a simple proposition however, for having one's assumptions challenged is not a process likely to be readily embraced by decision makers. To challenge a person's' thinking requires a safe forum in which risk taking is perceived as acceptable, and where an objective outsider is present to encourage confrontation of existing beliefs and to insure that less popular opinions are heard.

Empirical Support for Abbreviating the Model Building Process

While ideally it is desirable to have management teams involved in all aspects of creating system dynamic models, there is often insufficient time and opportunity for managers to meet together and undergo all activities involved in model conceptualization, quantification and experimentation. As a result, an emerging trend in the system dynamics community has been the discovery of new and different ways to undertake the model building process so that the time spent in modeling can be used most effectively (Eden, 1994). One outcome of this experimentation is that many practitioners are finding significant *benefits* in utilizing just one of the two primary sub-activities of the system dynamics model building methodology and are focusing their attention on either conceptual model building (e.g. Coyle & Alexander, 1997; Hodgson, 1994; Rosenhead, 1989; Wolstenholme & Coyle, 1983) or simulation (e.g. Cavaleri & Thompson, 1996; Sterman and Senge, 1994).

What follows is a review of the studies that have used either conceptual modeling or simulation as stand-alone interventions to teach managers about complex system behavior. The research articles described here are distinguished along three lines: 1) those studies that report on efforts utilizing only conceptualization such as the creation of a "cognitive map" (Eden, 1989) that depicts the system under study by representing the meaning of a concept through its relationships to other concepts; 2) those efforts that involve only simulation via a "management flight simulator" (Morecroft & Sterman, 1994); and 3) those studies that compare the case analysis method (a conceptual modeling task) to gaming (a simulation task) in a business education setting.

Empirical Studies on Conceptual Modeling Without Simulation

In the last few years, preliminary studies that support the use of qualitative or conceptual modeling for bringing about organizational learning have begun to emerge in the system dynamics literature (e.g. Huz, et al., 1996; Vennix, et al., 1996; Wolstenholme, 1994). In a study exploring the effectiveness of group model building techniques, Vennix, et al. (1996), reviewed cases involving conceptual modeling (the creation of a system dynamics causal map) in order to evaluate whether group model building could induce, in a time efficient manner, the kind of change in management attitude and behavior considered necessary for sustaining organizational success. Their findings were in keeping with those of Huz et al. (1996) who observed that following conceptual model building, participants were in greater alignment with regard to the goals of the organizational system but demonstrated no increase in alignment regarding *strategies* for change. That is to say, they developed more agreement on what the problem *was* but no further agreement on what to *do* about it. Even though participants in the Vennix et al. study said that there was considerable insight into the problem and that the process was effective in revealing relationships and feedback processes between problem elements, they did not feel that their initial *opinions* had changed much, suggesting that no change in mental model occurred, or that if it did, that participants were not able to distinguish this change. Overall, analysis of the individual workbooks used in the study indicated that the number of variables identified increased following the intervention, concepts became more detailed, and new relationships were added.

Empirical Studies on the Effectiveness of Simulation in Altering Mental Models

Although the use of management flight simulators or microworlds as an effective tool in management development has generated some controversy (Bakken, et al., 1994), recent evaluation studies (e.g. Akkermans & Vennix, 1997; Bakken, et al., Doyle, et al., 1996) support their use for enhancing users' mental models. For instance, in a study by Doyle et al. (1996) in which half the subjects were allowed to play a simulation game designed to coincide with data demonstrating a particular organizational dynamic, some participants showed significantly different content in mental models, an outcome they attributed to the use of the simulation. Doyle et al. noted that the new mental models did not *replace* the original mental models but were integrated into them as many of the participants in the study added additional variables to describe the system dynamics. In considering this outcome, Forrester (1975) might say that the computer model in essence served as an additional voice in the ongoing conversation that stimulated a greater array of 'possible' cognitive associations.

In some cases, the use of simulation has led to learning at the organizational or policy level. In experiments in which only a management flight simulator was used, Bakken, et al. (1994) report that when there was a difference in the mental models of two participants, the management flight simulator provided a framework for discussion which ultimately led to a reconciliation of their opposing views and prompted one of the participants to instigate changes in his organization's incentive policy. In another case study, Senge and Sterman (1994) cite Bergin and Rusko (1990) who quote a participant as saying, "Before the lab, I would have said the lack of quality was the only important factor. After the lab, it was obvious to me that productivity was also a key issue [s]o I restructured some units to enhance their ability to settle claims." (p. 35).

Lastly, research by Cavaleri and Thompson (1996) suggests that there may be specific factors such as the backgrounds of the users that influences the extent to which benefits may be derived from simulation use. In a questionnaire administered following the use of a computer simulation by four groups of business students and managers, Cavaleri and Thompson observed that managers, more than students, reported the microworld to be useful and effective for deepening their understanding of management practice.

Widening the Theoretical Net: Studies Comparing the Case Method to Gaming

Business schools have long utilized case study and simulation or gaming methods to provide an experiential approach to teaching business strategy (Wolfe, 1976). While management simulations differ from games in terms of the degree to which individuals give input and make decisions, many experts view simulations and games as synonymous (e.g. Lane, 1995). Likewise, the case study method which is characterized by an analysis of those variables considered most critical to the problem is very much like the conceptual modeling process of system dynamics in that they both encourage managers to think strategically, view the business as a whole, and adopt the perspective of the general manager (Graham, et al., 1994).

Research by Moore (1967), Strother (1966, cited in Wolfe, 1975b), Wolfe (1973; 1975a; 1975b) and Wolfe & Guth (1975) compared the relative contributions of the case and gaming methods to students' understanding of business issues. Overall, results of these studies have been contradictory. In one study, Moore (1967) found that games utilized in business policy teaching were *not* superior to traditional methods in teaching production management, while Wolfe (1973) and Wolfe and Guth (1975) found that the use of games in teaching business policy *were* superior to those of case teaching - but only *if* teacher guidance and structure were provided.

Wolfe's (1973; 1975a) research supports the importance of effective communication in student performance in simulated business environments. Wolfe (1975a) looked at effective performance of business students who utilized a simulated policy and decision making environment and found that, among the behaviors exhibited that were associated with successful performance were: a) formulating a long run strategy or plan; b) talking with other individuals during play; c) quantifying statements and rationalizing techniques; d) taking ample time for discussion among team members; d) taking an experimental and questioning attitude; and e) demonstrating flexibility in the face of changing conditions.

In a second study, Wolfe (1975b) pointed out the importance of facilitation in the learning process when he compared a traditional teaching approach (first structuring and then leading the learning process) to an experiential teaching approach in which the instructor role was largely passive once the initial learning structure was established. In a comparison of the amount and type of knowledge acquired by each group using a six-question test before and after the play, Wolfe found no gain in test scores in the learning environment in which there was no facilitation of the learning process; while in the facilitated learning process using the traditional approach, a gain in overall knowledge and principle mastery was observed.

Finally, Strother et al. (cited in Wolfe, 1975b) observed that students who utilized gaming seemed to inconsistently apply decision making techniques ad hoc. He asserts that students in a gaming situation are often aware of issues or problems during play but fail to apply formal and rational analyses needed to solve them. He further notes that participants become so involved in play that they do not take time to objectively understand what they are doing. Many of these problems, says Wolfe, could be handled through facilitation of the process.

Summary and Implications of the Empirical Studies

While studies have been few in number, there are some findings related to the effectiveness of an abbreviated modeling strategy that provide a framework for undertaking an investigation to explore the nature of the relationship of group model building to mental model development. First, both conceptualization and simulation appear to provide the necessary frameworks that help make individually held mental models explicit and both appear to be effective to some degree in helping participants develop a deeper understanding of the issues at hand. Secondly, based on the studies reviewed here, it appears that simulation modeling may have a greater impact on decision making performance than conceptual modeling as demonstrated by the case studies in which modeling sessions resulted in specific changes in the organization. Lastly, studies involving the comparison of traditional case study method to experimental gaming techniques indicate that facilitation of the group's process may be critical to learning from these experiences even though the effect of facilitation on group productivity has, in the past, been questioned (e.g. Kaplan, 1979).

When change does not happen quickly in an organization it is often assumed that the intervention has failed. The observation that *time* is needed to form cognitive connections between old and new ideas stands in contrast to achieving time-saving goals by abbreviating the group modeling process. Given that there must be a balance between these two objectives - giving enough time to develop an understanding of the dynamics of a given system and keeping the process within a training or retreat time frame - the need for research that helps practitioners understand which methods are most effective and efficient takes on increasing importance.

A Theoretical Model of Mental Model Development from Group Model Building

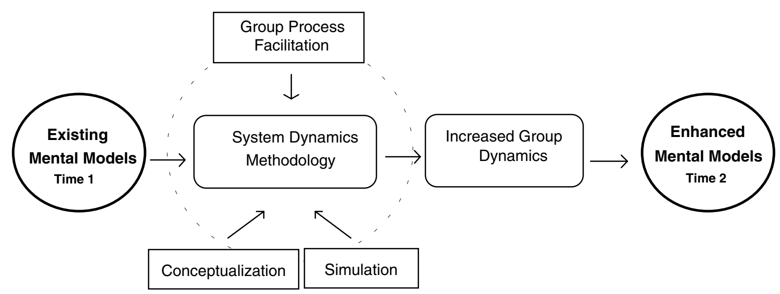

Figure 1

As described earlier, mental models can take many forms and represent different kinds of knowledge structures. For purposes of discussion here, the term mental model relates specifically to *strategic* mental models (a combination of declarative and procedural mental models which is developed through practice and experience) of complex organizational systems, that is, a bounded system of both structural and social components that reflects the flow of inputs and outputs of information, products, and people within a business context. A mental model of a complex system refers to the depiction in one's mind of what these components are, how they are interconnected, and what happens to them over time through the course of events. Further, facilitation is operationalized here as asking individuals to: make assumptions about interactions in the model explicit (describe); predict what will happen when a strategy is implemented (predict) and; explain results of outcomes following feedback on performance (explain). Finally, Group dynamics for these purposes refers to the observable level of group debate and discussion in a group problem solving forum.

In the theoretical model in Figure 1 it is proposed that with the application of the system dynamics framework, and through the utilization of group facilitation techniques, that: groups of individuals will effectively make their mental models of system structure and behavior explicit; will have opportunities to test their assumptions; and will be encouraged to revise their thinking if and when it is shown that their mental models and observable behavior are incongruent. Through these intervention strategies there will be an increased level of group dynamics. This increased interaction in turn is believed to serve as the catalyst for enhancing existing mental models so that they are altered from Time1 to Time2. That is to say: a greater number of variables will be identified, a greater number of connections between components will be articulated, strategies will become more detailed and proposed solutions will demonstrate characteristics that are properties of the "whole system".

In summary, it may be asserted that without increased group dynamics that result from a particular modeling strategy, level of facilitation or both, that initial mental models may not be significantly altered and that individuals will leave a group interaction with much the same content in their mental model as before the interaction. Without meaningful conversation that serves to unearth knowledge that may be otherwise unavailable or inert in memory and to stimulate the exploration of the dynamics of the complex system, interest in the model may not transcend the intellectual interests of the solo system dynamics modeler. Finally, without interaction of individuals in order to bring together an otherwise distributed cognitive network, to allow relevant experiential data to be tapped, or to challenge existing models of system functioning, little change in mental model content regarding strategy is likely to occur.

Evaluating Mental Model From the Two Modeling Interventions

Accepting mental model development as a meaningful indicator of the effectiveness of a group modeling technique requires that the mental model construct be operationalized in a way that general theories about its development can be assessed. Of particular concern is demonstrating how an individual's mental model has changed as a result of a particular developmental intervention from what it was prior to the event. This calls for a measurement design that goes beyond self-report, post-study methods frequently used to assess the enhancement of mental models (Doyle & Ford, 1998) to one that incorporates repeated measures and multiple methods. Moreover, in order to argue that mental model development is mediated by group dynamics, it must be demonstrated that different levels of dynamics are in fact, present in groups that manifest characteristics of mental model development.

In the study underway at a major southwestern airline located in the southwestern United States, two experiments within one methodological framework are used to assess two constructs in the theoretical model - mental model development and group dynamics. The methodological framework is depicted in Figure 2.

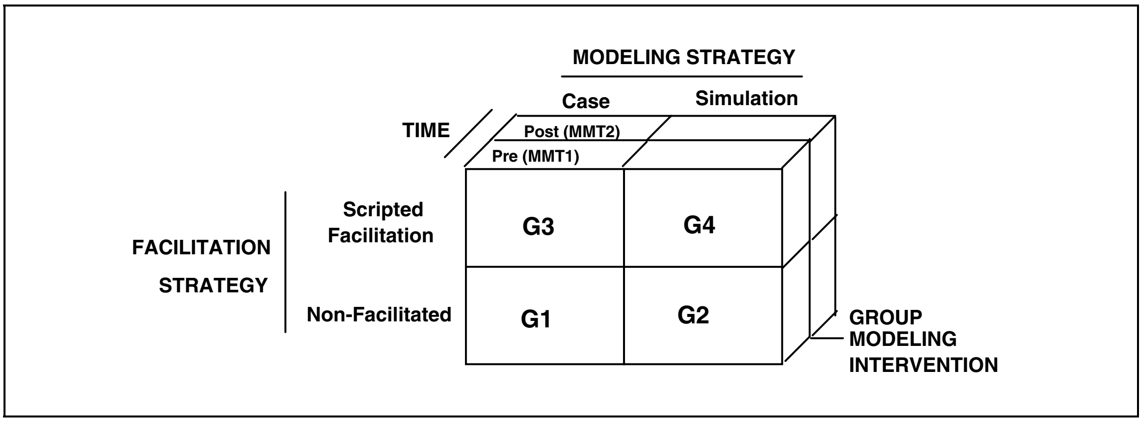

Figure 2

Measuring Mental Models - Experiment I

The aim of Experiment I is to test hypotheses related to two modeling strategies and two levels of facilitation on mental models. In the 2x2x2 repeated measure design shown in Figure 2, two levels of modeling strategies - *conceptualization and simulation,* and two levels of facilitation - *scripted facilitation and a non-facilitated* condition make up the experimental groups in each of four conditions (i.e. case with no facilitation; simulation with no facilitation, case with scripted facilitation and simulation with scripted facilitation). For purposes here, each experimental group serves as its own control group through the application of a repeated measures design.

Three indicator variables will be used to assess the extent of mental model development: a questionnaire, a relatedness ratings task and a diagramming task. Each of these measurement approaches is intended to tap into a unique aspect of the participant's mental model. First, a questionnaire is used to gather strategic knowledge about a general strategy for controlling the system. Second, the ratings task is used to assess participants' knowledge about the impact that each control variables has on the system. Third, the diagramming exercise is designed to unearth individuals' mental models about system structure and complexity.

Measuring Group Dynamics - Experiment II

Experiment II is designed to test the effect that modeling strategy and facilitation have on the level of group dynamics that occurs during the modeling process. Unlike the pre- and post-test design proposed in Experiment I, in Experiment II, the element of time is omitted leaving a post-test only design to assess the frequency of group interaction behaviors observed under each of the four treatment conditions. In this instance, the group process proceedings are recorded, categorized and quantified by two independent raters who are asked to count the number of times participants ask for or volunteer information, make an observation, offer a command or make a suggestion (ie. articulation/elicitation); indicate agreement or disagreement (ie. mental model challenge); or revise an earlier opinion (ie. mental model revision). Group dynamics is also quantified using an anonymous voting procedure to assess the level of agreement each individual has with the group's recommendation for controlling the system (Graham et al., 1994).

Final Remarks

Results of this study are expected by the fall of 1999. If you would like a summarized version of these results, please contact the author.

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