

The Role of Group Dynamics in Mental Model Development: An Experimental Comparison of the Effect of Case Study and Management Flight Simulator under Two Levels of Facilitation

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Abstract

Group Dynamics is theorized to play a pivotal role in how mental model development occurs as a result of Group Model Building. To test this theory, a two part experimental investigation was conducted. In the first part, Mental Model Development was assessed using two levels of group model building Method: case study and management flight simulator and two levels of Facilitation: non-facilitation and structured facilitation.

In the second experiment, the four experimental conditions were retained and the original sample was divided into fourteen sub-groups that worked together to develop a team strategy for a hypothetical change management task. Audio recordings of the activity were analyzed for comments related to strategy, process, rationale and facilitation. A second measure assessed participants' perceived level of agreement with and input on their group's final strategy. This paper describes the results of this second experiment and discusses outcomes in relation to the findings from Experiment I.

Key Words: Group Dynamics, Management Flight Simulator, Case Study, Mental Models, Facilitation, Group Model Building

Introduction and Overview

As our knowledge-based society unfolds (Reich, 1992), the need for team-based learning processes that support strategic decision making in organizations and facilitate the development of shared mental models is expected to grow (Akkermans & Vennix, 1997; de Geus, 1988; Morecroft & Sterman, 1994; Randers, 1976; Senge, 1990a; Stata, 1989; Vennix, 1996). While interest in group-based modeling processes to enhance organizational learning capabilities is on the rise, there have been only a handful of studies that empirically evaluate effectiveness of variations in approaches. In an effort to address this need, a two part investigation was conducted at a major airline located in the southwestern United States. The research upon which this paper is drawn consisted of two experiments. The first looked at if, and how, model conceptualization, simulation and facilitation of these two modeling processes contribute to the elaboration and revision of individually held mental models (for further detail see the 2001 System Dynamics Conference proceedings or contact the author). As the level of group dynamics is purported to be an important component of mental model development, the purpose of the second experiment was to better understand the impact that the two methods: case study and management flight simulator; and two levels of facilitation: non-facilitated and scripted facilitation had on the person to person interaction that resulted during a group-based modeling activity and on the level of participant buy-in to the process and its results.

This paper consists of three parts. The first describes in the theoretical and empirical foundation needed to better understand the impact of modeling method and facilitation on group dynamics. The second part outlines the experimental model, procedures and results. The third part of this paper discusses results in relation to outcomes from the first experiment pertaining to mental model development and discusses implications for theory, research and practice.

Part I Theoretical and Empirical Foundation

Mental Models and Organizational Learning

Mental models are believed to be important to organizational success because it is through their development and transference across group members the collective process known as “organizational learning” is said to occur (Gary & Charyk, 1996; Kim, 1993a; Morecroft & Sterman, 1994). By organizing a group’s knowledge into a *collective* framework and allowing for discussion regarding the validity of the framework (Zohar, 1997), individually held mental models may be revised to more closely align with a shared view of the organizational system (Größler, 1996; Lane, 1994; Morecroft & van der Haijden, 1994; Senge, 1990a; Stata, 1989). Inherent in this theory of shared mental models is the belief that individually held mental models may be altered as a result of person-to-person interaction. When ideas are discussed and debated, mental models may be altered as the brain forms new concept “associations” (Luria, 1973). As a result, new information may be added or current mental data rearranged to form new connections between concepts resulting in greater coherence or robustness of the original mental model (Morecroft, 1994). A more coherent mental model is one in which the concepts contained are rational, logically consistent with each other, have no mutual contradictions, and reflect interactions between the systems components and higher level effects that are built up (Lane).

Altering Mental Models with System Dynamics Methodologies

To describe how the system dynamics 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. The first stage, mapping mental models, is based on the premise that mental models can not evolve unless they are first made explicit (de Geus, 1988; Forrester, 1975). This is accomplished by having participants talk about and answer questions about the variables they see as important to system functioning. In talking with one another, group members may relate examples from their domain specific experiences, and in the process, make these mental models explicit and known to others in the group (Bakken, Gould & Kim, 1994; Eden, 1989; Narayanan & Fahey, 1990).

In the second validation stage of mental model development, an attempt is made to uncover internal contradictions, inconsistencies or incompleteness in previously articulated thinking (Senge, 1990a). For example, in a learning session utilizing a computer-based simulation - a "management flight simulator" Bakken et al. (1994) reported that participants thought that the workload assumptions made for an insurance adjustment claims task were incredibly light compared to what they should be. When asked what made the revised numbers the right ones, the participants reported, "Because it had always been that way". In that instant, the participants are said to have realized how this unquestioned assumption had been a driving force in their decision-making and contributed to their group's poor performance (Bakken et al.).

Senge and Sterman (1994) assert that mental model articulation is a necessary precursor to mental model development as, only after people have gone public with their mental model can they begin to discover inconsistencies and contradictions with other sources of information. Further, not until these contradictions are *resolved* should it be expected that individuals will move to the third stage of mental model development involving the revision of potentially erroneous assumptions (de Geus, 1988; Senge & Sterman). Even if these first three criteria are met, it should not be expected that a mental model will be readily revised however (Senge, 1990a), as new conceptual perspectives are assimilated gradually (Levitt & March, 1988) and sometimes not at all if current models, though perhaps simpler, seem to function satisfactorily (Woods et al., 1994).

Group Model Building

Over the last several years, system dynamics modelers such as Vennix (1996), Lane (1994), Morecroft and Sterman (1994) and others (see for example the special journal of the *System Dynamics Review*, Summer, 1997) have explored the process of building system dynamics models with groups of individuals from a variety of organizations. According to Morecroft and Sterman (1994), three defining characteristics of the group model building approach are: client ownership of all analytical work performed; models created through group process; and consultant acting as facilitator of group process to capture team knowledge. The group model building methodology is based on the idea that models should capture the knowledge and mental data of policy makers and should support team reasoning through the development of a more systemic and dynamic perspective (Morecroft & Sterman; Senge 1990a; Senge & Sterman, 1994). Through group interaction and the discussion of business issues, group model building is believed to enhance team learning, foster consensus and build commitment in decision making (Vennix, 1996).

Advancing the Use of Group Model Building through Abbreviated Interventions

One drawback to the group modeling approach is that building a model from scratch and developing it to the stage of policy experimentation requires a substantial time investment. Even with improvements in computer technology that have made the modeling process much easier and more accessible to non-experts, building a model that leads to meaningful insights may take two or more years to complete (e.g., Isaacs & Senge (1994); Vennix, 1996). As a result, group model building efforts must be designed to leverage as much learning from the process as possible when working within a shortened time frame with limited opportunities to work together as a group (Gary & Charyk, 1996). To achieve the desired goals within this narrow scope, the group may focus on only one aspect of the overall system dynamics modeling process. They may focus on conceptual modeling in an effort to generate a shared understanding of the problem from which to act (e.g., Checkland, 1989; Eden, 1989; Rosenhead, 1989; and Wolstenholme & Coyle, 1994) or focus on simulation by utilizing an already operating model to conduct policy experimentation (e.g., Paich & Sterman, 1993; Senge, cited in Morecroft & Sterman, 1994; Sterman, 1989).

The Role of Facilitation and Group Interaction in Group Model Building

Facilitation is widely regarded as critical to group model building success (e.g., Morecroft & Sterman, 1994). With the aid of a facilitator, individually held assumptions about how the system functions may be elicited and challenged. In addition to encouraging debate among group members, facilitation is asserted to make unique contributions to achieving the learning objectives in each of the two abbreviated group modeling approaches. According to Morecroft and Sterman, during model conceptualization, a facilitator may help ensure that all group members' ideas and opinions are heard and reflected in the conceptual model. During simulation, a facilitator may be instrumental in making sure that policy experiments are carried out in a scientific manner and rationale for changes in strategy are articulated. In either approach, facilitation may be important on a rudimentary level as it may serve to foster group interaction, a factor asserted to play a central role in mental model development.

The Role of Social Interaction in Mental Model Development

It is asserted that in the process of group model building that group interaction plays an important role in mental model development (e.g., Lane, 1994; Morecroft & Sterman, 1994; Vennix, 1996). This assertion is based on the idea that mental models may be enriched the longer a person *thinks* about a topic (Morecroft, 1994; Woods et al., 1994). When group interaction occurs, people may bring to mind more facts and concepts than they would in isolation. This enhanced recall may result in cognitive models that 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). Forrester, asserts that "within one individual, a mental model changes with time and even during the flow of conversation. The human mind assembles a few relationships to fit the context of discussion. As the subject shifts so does the model..." (p. 199). Observations by Anderson, Tolmic, Howe, Mayes & MacKenzie (1992) support this idea. Based on videotapes of an 'interactive protocol' – a live exchange between people working on a task - they observed that working with a peer resulted in improvements in the subjects' mental models used for prediction, particularly if the individual contrasted his or her pre-test predictions with those of another and then entered into discussions as to possible explanations of the phenomena.

When considered from a cognitive psychology 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 – spatial working memory and phonetic working memory (Wickens, 1992). Spatial working memory, which represents objects in visual or spatial form, may be tapped by the *visual* aspects of the modeling process while, verbal or phonetic working memory, which represents information as words or sounds, may be tapped by the *discussion* aspects of the process. This duality of input may prove instrumental to learning. Since these two forms of working memory are thought to be complementary, they do not necessarily draw on the same memory resources. If so, there may be more cognitive resources to devote to accessing information that may otherwise be latent. This enhanced recall by extension, may foster a more cognitively complex network of concepts to draw on during decision-making. This in turn, may increase the potential for mental model enhancement.

It can not be said categorically that group interaction will necessarily improve problem solving performance however, as it may aid performance in some groups and not in others depending on the dynamics that result. For instance, if one individual dominates group discussions so that participation is not equal among group members (Bakken et al., 1994; Eden, Jones & Sims, 1983; Hodgson, 1994; Vennix & Gubbels, 1994). To guard against such an occurrence, a neutral third party or ‘facilitator’ may be added to the group mix to inquire into the meaning of statements, ensure that all group members’ contributions are heard and to mediate group members’ opposing views.

Theoretical and Empirical Support for Abbreviating the Model Building Process

Even though it is desirable to have decision-making teams involved in all aspects of the modeling process, limitations in time to meet as a group make this difficult. Hence, there is a growing interest in reports of significant benefits derived when utilizing just one of the two primary sub-activities of the system dynamics model building methodology. When employing an abbreviated group model building effort, the focus is on either the conceptual model building (e.g., Coyle & Alexander, 1997; Hodgson, 1994; Rosenhead, 1989; Wolstenholme & Coyle, 1983) or the simulation aspects of the system dynamics process (e.g., Cavaleri & Thompson, 1996; Sterman & Senge, 1994).

Studies that employed one of the two primary components of the group model building process are reviewed in the next section of this paper are organized along three lines: 1) studies that evaluate conceptualization-only efforts or the development of a group derived “cognitive or causal map” that shows how key variables and concepts in the system relate to one another; 2) efforts that evaluate outcomes from simulation-only efforts using a “management flight simulator” - a computer-based learning environment embodying a system dynamics model; and 3) studies that empirically compare the case analysis method (a conceptual modeling task) to gaming (a simulation task) in a business education setting.

Theoretical Relationship of Model Conceptualization, Group Dynamics and Learning

The conceptual model may be used to initiate in-depth discussion and debate about the relationship between structure and behavior in the real system (Lane, 1993; Richardson & Andersen, 1995; Stevenson, 1993). Once agreed upon, this shared understanding helps group members prepare for taking the actions necessary to achieve their objectives (Rosenhead, 1989). Moreover, because conceptual models generally use a simple, symbolic language to show

connections and causal relationships between elements in the system, they may effectively convey ideas in a way that can be understood by people from a variety of different backgrounds and disciplines (Espejo, 1994). In conclusion, it may be posited that conceptual model building provides a unique mode of communication that encourages group interaction.

A primary aim in conceptual model building is to reach some agreement about the nature of the problem so that each group member feels committed to finding an appropriate solution (Checkland, 1989; Eden, 1989). When debating the nature of model structure, mental models may be altered as a group seeks agreement on the structure of system variables, boundaries, process flows, and information feedback loops (Randers, 1976; Stevenson, 1993; Vennix, Andersen, Richardson & Rohrbaugh, 1994).

In the last few years, preliminary studies that support the use of conceptual modeling using system dynamics methodologies for bringing about organizational learning have been reported in the system dynamics literature (e.g., Huz, Andersen, Richardson & Boothroyd, 1996; Vennix et al., 1996; Wolstenholme, 1994). In a study exploring the effectiveness of group model building techniques, Vennix et al., reviewed cases involving conceptual modeling in order to evaluate whether group model building could induce in a time efficient manner, the kind of strategic learning and change in attitude and behavior considered necessary for organizational success. Their findings were in keeping with those of Huz et al. who reported that following conceptual model building, participants were in greater alignment about the goals of the organizational system but demonstrated no increase in alignment in perception regarding *strategies* for change. In other words, groups 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 reported having gained considerable insight into the problem and said that the process was effective in revealing relationships and feedback processes between problem elements, they felt that their initial opinions had not changed much. This suggests that no change in participants' mental models occurred, or that if it did, participants were unable to distinguish this change. Overall, the effort was viewed as a success as analysis of the individual workbooks used in the study indicated that the number of variables identified by participants in the post-assessment increased (almost no variables were removed), concepts became more detailed, and new relations between variables and feedback processes were added. This suggest that the interaction process was effective in the enhancement of mental models.

In summary, outcomes from the Vennix et al. (1996) study indicating greater consensus around the problem but no agreement on potential courses of action were supported by Huz et al. (1996) and fit with assertions made by Doyle et al. (1996) who posit that group consensus and a shared mental model are not the same thing. In conclusion, it may be possible to achieve group consensus regarding the nature of the problem without developing a shared mental model that translates into collective or coordinated action. From a research standpoint it may be expected that individuals would perceive higher levels of input on a chosen strategy while at the same time perceiving lower levels of agreement with the strategy.

Theoretical Relationship of Model Simulation to Group Dynamics and Learning

The use of system dynamics computer-based simulations, also known as 'management flight simulators' or 'microworlds' (Sterman & Morecroft, 1994) is the second approach often in an abbreviated group model building process. A management flight simulator is a computer-based learning environment based on a previously developed model that allows people to experiment

with the model without having to build it from scratch (Senge & Sterman, 1994). Once a conceptual model is developed and the relationships depicted are quantified using specialized computer software (e.g., *iThink* by High Performance Systems) a computer interface or “cockpit” is added so that users can easily manipulate a range of model assumptions. The resulting “management flight simulator” can then be used for policy experimentation. Computer-based simulations, or management flight simulators, are said to be effective for enhancing mental models because they provide a framework for clarifying mental models through controlled experimentation; a forum through which assumptions can be questioned in a non-threatening way; and opportunities for participating in ongoing debate regarding strategy change; and feedback on performance that may lead to insight into how the system functions under various conditions (Bakken et al., 1994; Diehl, 1992; Größler, 1996; Lyneis, Reichelt & Sjoblom, 1994; Morecroft, 1988).

When using system dynamics simulations to achieve learning objectives, emphasis is placed on the experimentation aspects of the group model building process (Wolstenholme & Coyle, 1983). As users try something, see how it works, seek to understand how the system structure facilitated or defeated the action and then try again, they can see how the assumptions they make about system structure and processes may play out over time (Stevenson, 1993). This repeated experimentation may contribute to a deeper appreciation of the dynamics of the system and the feedback processes that produce them (Paich & Sterman, 1993) and may in some circumstances lead to improved decision-making (Cavaleri & Thompson, 1996; Lyneis et al., 1994; Morecroft, 1988; Stevenson) and contribute to organizational learning (de Geus, 1988; Simon, as cited in Morecroft).

One of the reasons that model simulation is believed to be effective is that it may play a vital role in the “validation” stage of mental model development. When the dynamics observed are counter-intuitive to users’ expectations, they may experience a surprise reaction (ie., an ‘aha’), an emotional response considered critical to learning (Argyris & Schön, 1996; Luria, 1973; Restak, 1984; Wack, 1985b). If given an opportunity to reflect on a surprising outcome, users may be prompted to modify their preexisting models so that they are more in line with the new discovery or, if they believe this outcome is invalid, they may recommend changes be made to the underlying simulation model so that it more closely matches their perceptions of reality (Argyris & Schön, 1978; Größler, 1996; Williams et al., 1983). There are, of course, other less desirable outcomes possible. A counter-intuitive result may also lead to the rejection of the model altogether particularly if it is not viewed as an adequate representation of the context being explored (Doyle et al., 1996; Lane, 1995; Wack, 1985a, 1985b) or to no response at all (Woods et al., 1994) if a relevant context has not been established.

Recent evaluation studies support the use of management flight simulators for enhancing users’ mental models (e.g., Akkermans & Vennix, 1997; Bakken et al., 1994; Doyle et al., 1996). In a study by Doyle et al. 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 the researchers attributed to the use of the simulation. They also noted that the participants’ post-experience mental models did not *replace* the original models but rather, that what the participants learned from the simulation was integrated into them as evidenced by the addition of variables to assessed models.

Research by Cavaleri and Thompson (1996) suggests that there may be specific factors such as the backgrounds of the users that influence the extent to which simulation may be expected to contribute to learning. In a questionnaire administered following the use of a computer simulation, they observed that, managers more than students, felt that the microworld helped deepen their understanding of management practice. Even though it might be expected that the simulation context was closer to managerial experience, this finding suggests that effectiveness of these methods may be contingent on specific conditions. Three conditions advocated as essential to insuring effectiveness of simulation are that it must be: incorporated into a planned learning framework; relevant to the backgrounds of the users; and designed so that users can grasp the underlying model dynamics driving simulation performance.

Empirical Studies Comparing the Case Study 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). The case study method which is characterized by an analysis of those variables considered most critical to the problem, is similar to the conceptual modeling in that both encourage managers to think strategically, view the business as a whole, and adopt the perspective of the general manager (Graham, Morecroft, Senge & Sterman, 1994). While management simulations differ from games in terms of the degree to which individuals give input and make decisions, many experts in the field view simulations and games as synonymous (Lane, 1995). Given these similarities, studies that evaluate the effective use of case study and gaming methods may be considered alongside those pertaining to model conceptualization and simulation. This creates a wider base of literature from which to draw on in establishing an empirical foundation regarding the effectiveness of abbreviated group modeling methods and the role that group dynamics plays. A review of the relevant case and gaming studies follows.

Moore (1967), Strother (as cited in Wolfe, 1975b), Wolfe (1973, 1975a; 1975b) and Wolfe and Guth (1975) compared the relative contributions of the case and gaming methods to students' understanding of business issues. Overall, it may be said that results of these studies have been contradictory. While Moore found that games utilized in business policy teaching were *not* superior to traditional methods in teaching production management, Wolfe (1973) and Wolfe and Guth found that the use of games in teaching business policy *were* better than traditional case study methods *if* guidance and structure were provided.

Wolfe's (1973, 1975a) research points to 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 several behaviors that were associated with successful performance. Among them were: formulating a long run strategy or plan; talking with other individuals during play; quantifying statements and rationalizing techniques; taking ample time for discussion among team members; assuming an experimental and questioning attitude; and demonstrating flexibility in the face of changing conditions.

In a second study, Wolfe (1975b) pointed out the importance of facilitation in the learning process. In this study he compared a traditional teaching approach where the instructor leads the learning process to an experiential teaching approach in which the instructor's role is largely passive once the initial learning structure is established. In comparing the quantity 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 a non-facilitated learning process. In contrast, he observed a gain in overall knowledge and principle mastery in a facilitated, traditional approach condition.

Finally, Strother et al. (cited in Wolfe, 1975b) observed that students who utilized gaming demonstrated erratic decision-making behavior as they applied their decision-making techniques ad hoc and inconsistently. 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 also noted that participants became so involved in play that they did not take time to objectively understand what they were doing. Many of these problems could, asserts Wolfe, be eliminated through facilitation of the process.

Theoretical Model of the Role of Group Dynamics in Group Model Building

The number of studies upon which to form a general theory of mental model development as a result of system dynamic methodologies are few and, in general, are often dependent on case study methods and self-report measures. Even though limited in scope and number however, when taken together, these preliminary evaluations form a starting point for exploring the effectiveness of group model building and point the way for the formation of a general theory for the role that group dynamics plays in mental model development.

In the illustration in Figure 1, the application of the system dynamics methodology comprised of either conceptualization, simulation, group process facilitation or any combination of these practices, is asserted to increase the level of group dynamics observed in the group’s interaction. 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.

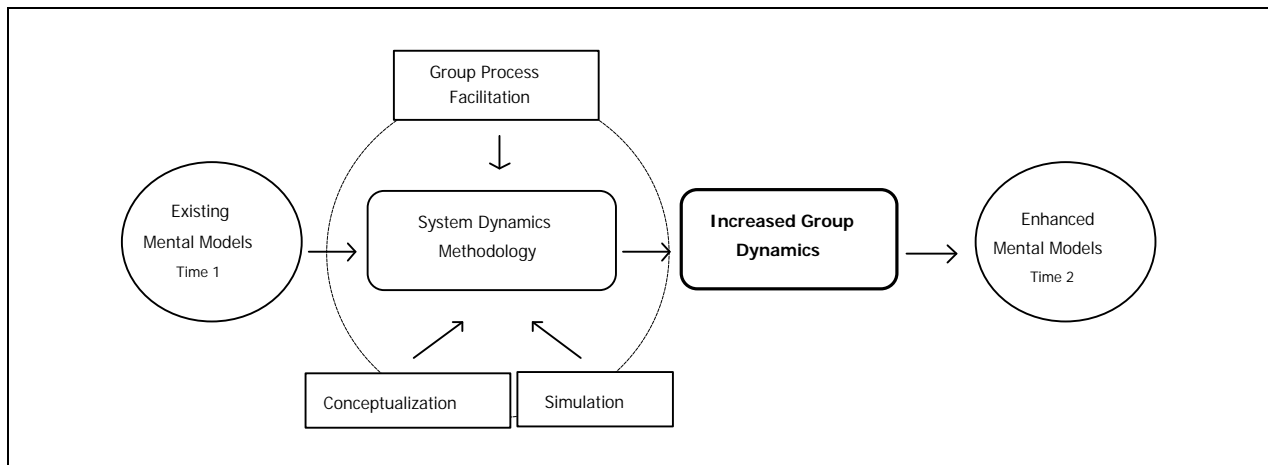


Figure 1 The Theoretical Role of Group Dynamics in Mental Model Development

In the theoretical model of Figure 1 it is proposed that the sub-components of the system dynamics methodology work together with group facilitation to moderate mental model development in a group model building situation. It is further inferred that, while both modeling method and facilitation may have an independent impact on mental model development, this effect may be greatest when methodology and facilitation are combined. The rationale for this assertion is twofold. First, both modeling method and facilitation have the potential to increase the level of productive discussion while at the same time reducing negative defensive behaviors in the group

interaction process. Second, while both methods help make mental models explicit, facilitation may take this process one step further by encouraging individuals to consider how valid assumptions being made are to the current context. It is posited here that unless the modeling framework and effective facilitation are used together, mental models may evolve simply as a function of time but not to the extent possible when both method and facilitation are used together. The reason for this is that both variables contribute meaningfully and reciprocally to the other and in so doing, increase the level of group interaction or dynamics.

Defining Group Dynamics

Group dynamics is operationalized here as *the observable level of group debate and discussion in the group problem solving forum*. To that effect, increased group dynamics implies that there are greater levels of these behaviors as a result of a particular group model building strategy. Previously it was said that group discussion was an integral part of mental model development because it serves to unearth knowledge that may be otherwise unavailable or inert in memory. The implication of this assumption is that hearing another speak about a topic may stimulate or trigger a thought in another and potentially, over time, allow individuals to develop cognitive connections between seemingly unrelated concepts in memory. In this way, effective person-to-person dialogue increases the potential for forming multiple links in a cognitive network as contributions by person A stimulate thoughts in person B. From a group modeling standpoint, when person B asks person A, “what do you mean when you say?” or, “why do you say that...?” this ongoing exchange may lead to further articulation of assumptions, followed by potentially more opportunities for debate. Further, facilitation of the dialogue process may magnify this discourse and bring more individuals with differing viewpoints into the discussion. As a result, person A may stimulate thoughts not only in person B, but in persons C and D as well. Likewise they, in turn, may stimulate thoughts in each other, creating an exponential increase in the potential cognitive network which may be developed as a result of group discussion.

As suggested previously, facilitation alone may not be enough for this elaboration of the cognitive network to occur. Without the ongoing framework provided by the modeling method, there may be little thought given to how the boundaries of the problem are defined and how the parts of the system interrelate. So, for example, during model conceptualization when person A, who possesses knowledge about Event 1, shares this information with person B and Person B in turn, offers their unique perspective on Event 2, the declarative and procedural knowledge of how the system functions may be enhanced for both members.

Group dynamics may also be affected by the modeling method when, during simulation modeling, individuals working as part of a team assert their opinions about which variables to use to achieve the greatest impact on system performance. If person A asserts that setting a variable assumption at a specific level will help control the system, persons B and C may urge him or her to explain the reasoning behind this assertion. Given adequate explanation by this individual, this assertion may then be tested. Depending on outcomes, the team may go on to discuss how results observed fit with their expectations and to consider the implications of these effects. In summary, it may be asserted that combining a particular modeling method with a meaningful level of facilitation may lead to group dynamics that alter individual thinking such that the preconceived notions about system functioning are altered.

Part II Description of the Research Effort

The following paragraphs introduce the two experiments that comprised the total study. In the first experiment, conceptual modeling via case study was compared to simulation modeling via a management flight simulator under two levels of facilitation in order to assess the effects of these modeling approaches on mental model development in a group setting. In the second experiment, the modeling methods and two levels of facilitation were further assessed to determine if, and how, these variables affected the observable levels of intra-person group interactions. The following section outlines the general design of these two experiments and the results that were expected in Experiment II, the focus of the this paper, under varying experimental conditions.

Overview of the Research

The aim of Experiment I was to test hypotheses related to two group modeling methods and two levels of facilitation on mental models. In the 2 x 2 x 2 repeated measure fixed effects design, two levels of modeling method - *conceptualization and simulation*, and two levels of facilitation - *scripted facilitated and non-facilitated*, made up the experimental groups in each of four conditions (i.e., case study with no facilitation; simulation with no facilitation; case study with scripted facilitation; and simulation with scripted facilitation). Each experimental group served as its own control group through the application of the repeated measures design, thus constituting an extension of the Latin Square design as described by Cook & Campbell (1979).

Experiment II was designed to assess the effect that modeling method and facilitation had on the level and type of Group Dynamics that could be observed during a group modeling activity. Unlike the pre- and post-test design used in Experiment I, in Experiment II, the element of Time was omitted leaving a fixed effects post-test only design as illustrated in Figure 2. The aim of Experiment II was to assess the level of group dynamics that occurred as a result of a group model building activity under each of the four treatment conditions.

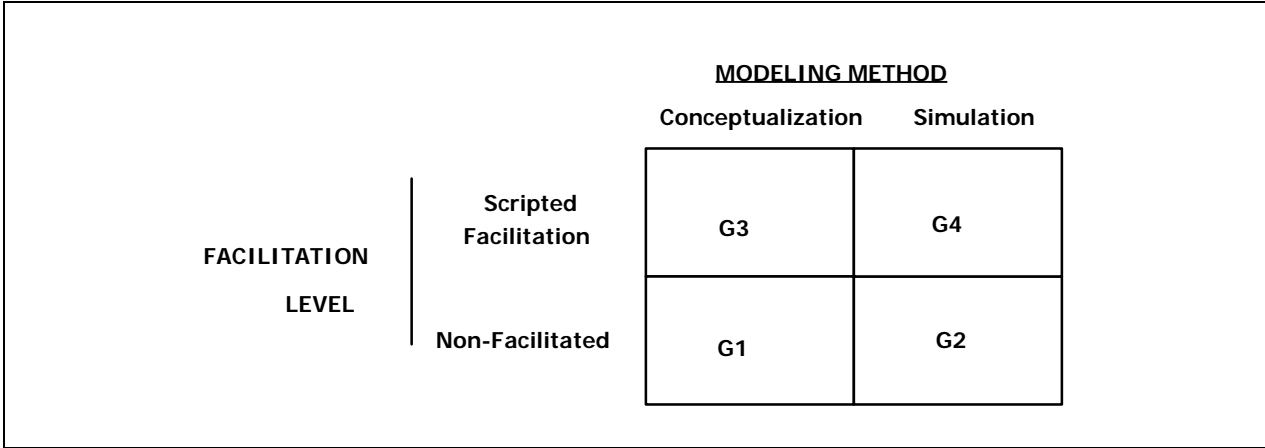


Figure 2 Fixed Effects Post-test Design Used for Experiment II

In the 2 x 2 matrix of Figure 2, the randomization of the participants in the study to various treatment conditions sufficed for the lack of a pre-test (Campbell & Stanley, 1963). In this experiment, the effect of facilitation on group dynamics was assessed by comparing the intra-person interactions that could be observed in Groups 1 and 2 (non-facilitated) to those observed

in Groups 3 and 4 (facilitated). Similarly, in order to test the effect of the modeling method on group dynamics, the results of Groups 1 and 3 (conceptual modeling) were compared with Groups 2 and 4 (simulation).

Description of Cell Components and Theorized Expected Outcomes

To facilitate a more complete understanding of the four cells depicted in Figure 2, each group as a treatment condition is discussed in terms of the level of group dynamics that each was expected to exhibit in the following paragraphs.

Conceptualization in a Non-Facilitated Group Session (G1)

In the non-facilitated conceptual modeling condition (G1), it was expected that the level of group dynamics would be less than other groups. As a 'leaderless' group, it was anticipated that there would be little discussion during the group session and that, lacking a facilitator, one or two group members would dominate discussion. Hence, individuals would not perceive high levels of input from the process and discussion would center on just a few elements of the conceptual problem. It was also expected that verbalized opinions would be taken at face value with little prompting for further discussion regarding the reasoning behind these expressed ideas. Thus it was anticipated that there would be lower levels of discussion regarding rationale for a chosen strategy.

Simulation in a Non-Facilitated Group Session (G2)

When the simulation method was employed in a non-facilitated setting (G2), it was anticipated that the effect on group dynamics would be much like those observed in the non-facilitated conceptual modeling condition. As such, it was expected that one or two dominant members of the experimental group would assert their views for strategy with little rebuttal from other members of the group. It was further assumed that during the group activity, that some group members would not participate in the discussion while others that felt more confident in their opinions or with using the computer, would dominate the group's activities. Finally, it was expected that there would be little time spent discussing outcomes of the experiments, and that trials would continue one after the other in search of better performance without exploration as to why the simulation model reflected the outcomes that it did.

Effect of Facilitation Combined with Conceptualization (G3)

In the facilitated conceptual modeling group (G3), it was expected that group dynamics would be significantly different from either of the two non-facilitated conditions. It was anticipated that the facilitator would effectively draw out the opinions of the group members and encourage them to make their rationale for their assessments explicit. By posing questions such as, "why do you think this particular strategy will make a difference?" the degree of group dynamics would increase as members would be prompted to explain their rationale for their chosen strategy. This increased discussion would, in turn, lead to the generation of a greater number of potential solutions; raise the level of debate regarding the assumptions being made; and contribute to improvements in the group's ability to predict the impact of variables on system behavior. Moreover, by having the facilitator ask the group questions like, "Do all of you agree with Person A's assessment of the situation, why, or why not?" it was expected that the facilitator would effectively increase the level of perceived input on the final strategy.

Effect of Facilitation with Simulation (G4)

Finally, in the facilitated simulation group (G4) it was expected that the level of group dynamics would be greatest as emphasis on obtaining better results with each successive trial and determining how the system could be made to function most effectively would draw group member into discussion more. Further, it was theorized that because the simulation would effectively function as a transitional object for eliciting mental models, that participants would feel more comfortable making their opinions known and disagreements would be focused on the simulation output and its perceived accuracy to participants' experiences. Moreover, it was anticipated that the facilitator would help increase the level of discussion regarding rationale by asking for explanations to observed outcomes. This would elicit responses not only from the individual whose strategy was tested, but also from others in the group as well as they would be drawn into the group's performance challenge. Hence it was expected that the Facilitated Simulation groups would perceive higher levels of input on and agreement with final strategy and levels of comments related to rationale and strategy would be greater than in the other three conditions.

General Hypotheses for Experiment II

Based on the theoretical assertions made regarding the effect of model building method and facilitation on group dynamics, the following main and interaction effects were asserted.

Table 1 Summary of **Null** Research Hypotheses

Main Effects

Effect of Modeling Method

Ho₁: There would be a significant modeling strategy effects on Group Dynamics

Effect of Facilitation Level

Ho₂: There would *not* be a significant facilitation effect on Group Dynamics

Interaction Effects

Effect of Modeling Method x Facilitation Level

Ho₃: There would not be a significant modeling Method x Facilitation interaction

Measuring Group Dynamics

The Group Dynamics construct is operationalized as the observable level of group discussion as manifest by statements made during a group model building activity. Group dynamics was assessed with two measures, one a variation on the "think aloud" method and the other, an anonymous voting procedure. In the 'think-aloud' methodology proceeds by presenting individuals with a problem and asking them to isolate the key variables involved in controlling the system. Individuals are asked to verbally express all thoughts, while working to solve the problem within a pre-set time limit. For purposes of this study, a group activity served as a natural context for gathering 'think aloud' data. To do this, the group activity proceedings, or "think aloud data" was recorded, categorized and quantified. These audio proceedings were analyzed by having two independent raters count the number of times participants made suggestions for

strategy, provided rationale for their chosen strategy, proposed group process procedures or made comments intended to facilitate their group's process.

In addition to counting the behavioral incidences that occurred in each group session as recommended by Volpe, Canon-Bowers and Salas (1998), group dynamics was also be assessed with an anonymous voting procedure that took place after the group model building activity. This ballot (see example in Appendix ..) assessed the degree to which individuals felt their group's final strategy reflected their input and the degree to which they agreed with the strategy (Graham et al., 1994). This measure was analyzed with a five-point quantitative response scale. Figure 3 summarizes the two measures used to assess the group dynamics construct.

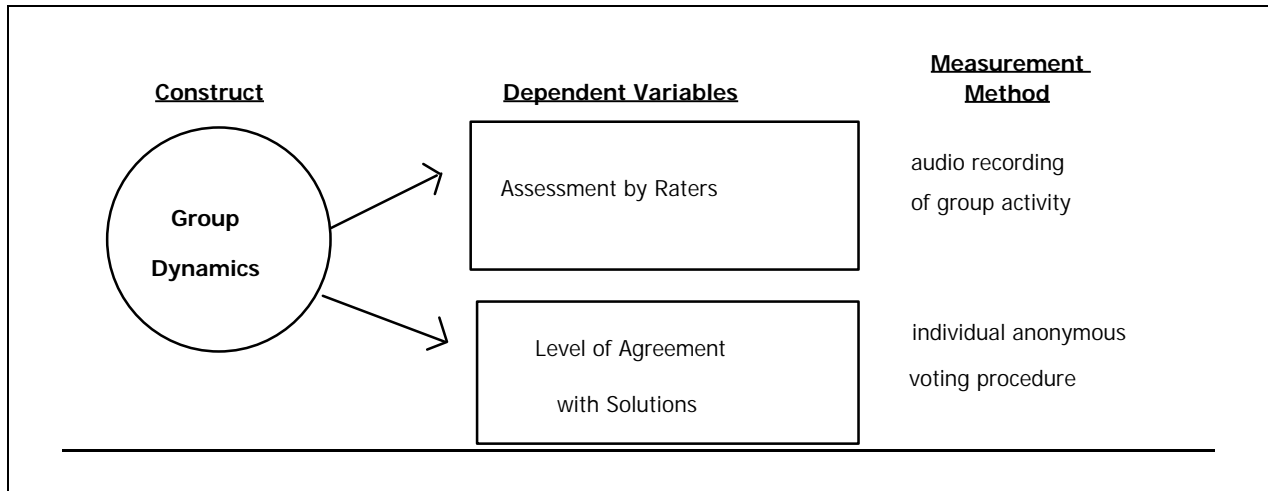


Figure 3 Dependent Variables and Measurement Methods Used in Experiment II

The Research Design

The purpose of the experimental design was designed to test whether Method and Facilitation had an effect on the intra-person dynamics that occurred during the group model building activity. As with the first experiment, Experiment II involved a fixed effects design involving two levels of Method - model conceptualization (case study) and model simulation (management flight simulator) and two levels of Facilitation - facilitated and non-facilitated.

As shown in Figure 4, for the research design, the original sample of 58 participants was divided into fourteen sub-groups comprised of four to five participants each. The use of sub-groups was based on the rationale that the larger the group, the fewer people participate in discussion and the more discussions tend to be dominated by a few group members (Bales et al., 1951 cited in Vennix, 1996). Limiting the size of the sub-groups to five was based on findings showing that a group size of five was optimal for ensuring group member satisfaction (Slater 1958, cited in Vennix).

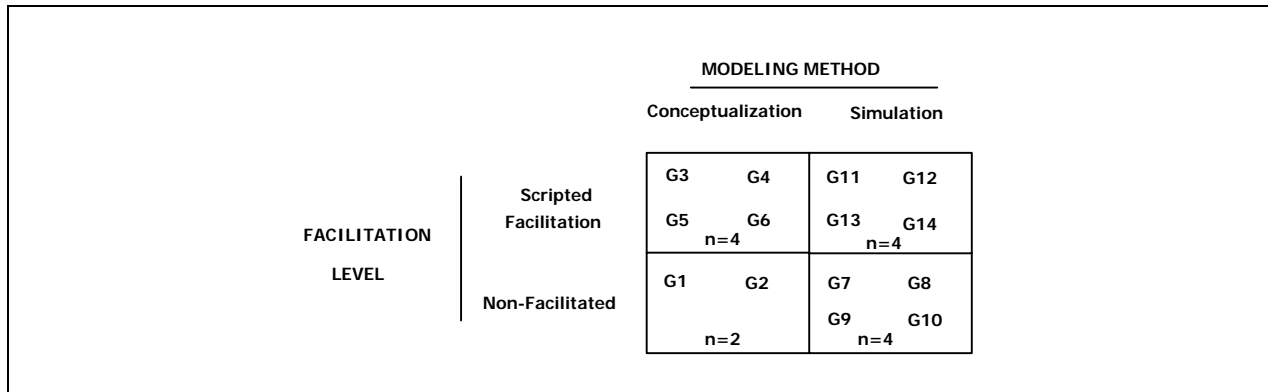


Figure 4 Experiment II Design to Assess Group Dynamics under Two Levels of Modeling Method and Facilitation

Experimental Procedures

Following an introduction to three general change management theories, a short orientation to Systems Thinking and a pretest used for assessing mental model development in Experiment I, participants in each of the four experimental sessions were randomly divided into sub-groups by having participants count-off from left to right across the room. For each experimental session there were two to four subgroups as shown in Figure 4. Once the groups were organized, half of the sub-groups moved to an adjacent meeting room while the remaining subgroup(s) organized their teams in a dispersed fashion in the primary meeting space. Once seated together, each of the sub-groups was given a team strategy sheet and instructed to record their team’s strategy, provide its rationale, and prepare to test their strategy using The Tipping Point management flight simulator when the larger group reconvened. Throughout the 50-minute time period in which the group worked together, their discussion was recorded on audiotape. Immediately following the group activity, participants returned to their original seating arrangements, answered two questions on the anonymous voting procedure and completed the posttest used for assessing Time effects in mental model development in Experiment I.

Dependent Variables in Experiment II

The two measures employed in Experiment II are described in greater detail below.

Measure 1 - Audiotapes of the Group Activity

Audiotapes of each sub-group were independently content analyzed by two trained raters. To prepare for this assessment the two raters reviewed records made during the pilot study and practiced, first together and then independently, categorizing the interactions that could be heard according to the descriptions provided on the pilot study coding sheet. Upon review, these classifications were refined to derive the assessment form used in Experiment II. The four types of statements assessed were selected based on their purported role in the development of mental models wherein mental models must first be articulated (i.e., comments on Strategy) in order to be examined for validity (i.e., comments on Rationale). Moreover, theoretical assertions about the benefits of a structured framework (i.e., comments on Process) and the proposed importance of including all group members in the discussion (i.e., Facilitative comments) guided the classification scheme. The four variables are detailed in Table 2.

Table 2 Experiment II, Measure 1 – Four Types of Comments Assessed from the Recorded Group Activity Proceedings

Variable Name	Operational Measurement
Comments on <i>Strategy</i>	number of times individuals proposed specific solutions to the problem
Comments on <i>Process</i>	number of statements made about how the group should carry out their task
Comments on <i>Rationale</i>	number of times individuals gave explanations for their approach
Comments on <i>Facilitation</i>	number of times individuals made comments that were intended to solicit input from others

Measure 2 – Anonymous Voting Procedure

The second measure of group dynamics was the post-activity voting process. In this procedure, individuals were asked to rate on a scale of 1-5, “the degree to which they agreed with the group’s final strategy” (Variable 5) and, “the degree to which they felt the group’s strategy reflected their input” (Variable 6). The rationale for including the voting procedure in the group dynamics construct was based on group model building theory (Graham et al., 1994) asserting that to the extent that group members feel that their team’s strategy reflects their input, the level of group dynamics that has occurred is said to be higher than in those groups in which individuals do not agree with the strategy and do not feel that the strategy reflects their input.

The variables used to assess Group Dynamics in Experiment II are summarized in Table 3.

Table 3 Summary of Group Dynamics Dependent Variables

Group Level Data	
Measure 1: <u>Audio Taped Recordings</u>	
Variable 1	Comments on Strategy
Variable 2	Comments on Process
Variable 3	Comments on Rationale
Variable 4	Facilitative Comments
<hr/>	
Individual Level Data	
Measure 2: <u>Anonymous Voting Procedure</u>	
Variable 5	Level of Agreement with Final Strategy
Variable 6	Level of Input on Final Strategy

The Experimental Field Site

Subsequent to a pilot study at a small electronics firm, the main experiment was conducted in June, 1999 at a major airline in southwestern United States. One of the advantages of participating in this study was that the sponsoring organization had an opportunity to expose their employees to a management flight simulator that, for nearly all participants, was a new method of training. In addition, the subject matter of the training - organizational change – was specifically of interest to the host organization as they were undergoing high levels of organizational change.

The Experimental Protocol

The experimental protocol used for this study was developed according to the learning objectives of the field site organization. These objectives included a desire to have all participants, regardless of their experimental group, receive some level of exposure to the management flight simulator and to engage in meaningful discussion around the issue of organizational change. The following experimental protocol was used for Experiment I and II.

Pre-Experimental Session Procedures

Prior to attending an experimental session, all participants were invited to attend one of the four experimental sessions offered. While the electronic invitation (ie., e-mail) sent out did not indicate whether individuals would participate in a conceptual or simulation-based session, they were informed that they would receive some exposure to the management flight simulator and were informed of the topic of the session – change management.

Experimental Session Procedures

Each experimental session began with introduction to the training including the purpose of the research; collection of an ‘informed consent form’ and sample demographics/screening questionnaire; an overview on *Organizational Models of Change*; and an introduction to *Systems Thinking*. The *Systems Thinking* orientation included how to label a causal-loop diagram using arrows, same/opposite or +/- labels, and system delay indicators. Depending on whether participants were in the Conceptualization or Simulation condition, they read a business case or observed an orientation to the Management Flight Simulator used. Both method orientations included an explanation of the six variables or “levers” that could be used to control the hypothetical organizational system and an overview of the organization’s objectives. Following the overview and introduction to the change management issue to be addressed, each participant completed a three-part pretest consisting of an open-ended question, a two part ratings task and a diagramming task. The results of this pretest were used in the analysis of mental model development which was the focus of Experiment I. This three part test was repeated following the group activity, the focus of Experiment II.

Group Activity Protocol

According to McGrath (1984), a small group should consist of two or more people but be small enough that individuals can be mutually aware of and potentially in interaction with one another. Following the pre-test, the group model building activity was described and study participants were randomly assigned to groups consisting of 4-5 people. All groups were given the same assignment: *to derive a strategy for implementing a change in a fictitious organizational system utilizing the six control levers described in the method orientation.*

The Case/Simulation Task

The use of hypothetical problems or test cases to conduct an analysis of problem solving reasoning is supported by prior research (e.g., ... et al., 1995). To reduce the possibility of prior exposure to the case/simulation task, a newly developed management flight simulator called The Tipping Point (Shapiro, 1998) was used in the simulation modeling condition and a business case based on the simulation’s underlying system dynamics model was written especially for use by participant’s in the conceptual modeling condition.

Those participants in the Conceptualization condition worked in small groups to conduct an analysis of the written case describing the organizational context, management challenge and potential mechanisms for controlling the system. Their strategy devised was to include the requisite level(s) of the six control levers the group would use and a prediction of what they thought would happen to the hypothetical organization's three populations of people over a five-year time frame if their strategy were employed. Participants in the Simulation condition used a laptop computer equipped with The Tipping Point to answer this same series of questions.

Facilitation Protocol

Depending on whether participants were in a facilitated or non-facilitated group, variations in assistance with group processes for completing the team objectives were provided. If participants were in a Non-Facilitated condition, they were instructed to use any group process techniques they chose to develop their strategy. If they were in a Facilitated condition, they were assisted by a trained facilitator (one of eight volunteers from a local Organizational Development professional association). The facilitator was instructed to guide the group through the case analysis with the aid of a pre-established script. Based on the theory that the purpose of mental models is to describe, predict and explain (Rouse & Morris, 1986) this script included a description of the facilitator's role and questions the facilitator should ask including, "what are the key relationships in the system?" (describe); "what makes these important?" (explain); and, "what will happen if you implement your proposed strategy?" (predict).

With the exception of assistance in how to operate the Management Flight Simulator, the Non-Facilitated Simulation groups were given no further guidance in completing the group assignment. Those in the Facilitated Simulation condition used the same scripted process used by the Facilitated Case groups. During the fifty-minute activity the group was to decide on a strategy and record it on the team strategy sheet given.

Post-treatment and Session Conclusion Procedures

After the fifty-minute group activity, participants returned to their original seating arrangement and completed the anonymous ballot designed to assess the degree to which they agreed with their team's final strategy and whether they thought their team's strategy included their input. Following the voting, participants completed the posttest – a repeat of the open-ended question, ratings, and diagramming tasks completed as part of the pretest.

As part of the workshop structure, the teams presented their strategies to the larger group detailing the level of each variable they used and their rationale. Each team's strategy was then tested using the Tipping Point management flight simulator and results of each "run" were displayed on a projected overhead image for all participants to view and discuss.

Part III Results and Discussion

Summary of Experiment I Results

The experimental hypothesis that facilitation level would significantly affect mental model development (H_{02} : Facilitation) was strongly supported ($p < .01$). A review of the variables analyzed in the univariate ANOVA analysis showed that facilitated groups performed significantly

better than non-facilitated groups on the Open-ended Question and Ratings Task I dependent variables but not on Ratings Task II.

The first and third experimental hypotheses pertaining to Method (H_{01} : Method) and Time (H_{03} : Time) were moderately supported ($p > .01 < .05$). Although significant from a MANOVA perspective, no significant method effects were discerned when the three dependent variables (Open-ended Question, Ratings Task I & II) were submitted to separate univariate analysis. In contrast, the hypothesis that Time would have a significant effect on performance and that participants would perform better on the posttest than they did on the pretest was moderately supported by MANOVA as well as by separate univariate analyses.

Of particular interest was the significant interaction between all three independent variables (H_{06} : M x F x T). The hypothesis that the Facilitation x Method interaction would not be invariant over time was moderately supported by the MANOVA analysis. Separate univariate ANOVA analyses were instrumental in providing insight as to the source and nature of the observed effect. When submitted to univariate analyses, significant three-way interactions were observed on Ratings Task I and Ratings Task II but not on the Open-ended Question dependent variables. A surprising finding was that the direction of the relationship between Facilitation and Method varied between these two measures. In comparing the posttest to the pretest scores, the Simulation groups in general performed better than the case groups by a wide margin on Ratings Task I and by a small margin on Ratings Task II. While the level of performance due to method alone remained fairly constant across the two variables, there was a striking contrast in performance when the effect of facilitation was considered. This contrast in results suggests that differences between the pretest and the posttest may be attributable not only to differences in the nature of these two measurement tasks but by the level of facilitation in the groups as well.

In summary, a key finding in Experiment I was that as posited, unless the modeling framework and effective facilitation are used together, mental models may evolve simply as a function of time but not to the extent possible when both method and facilitation are used together. The reason for this is that both variables contribute meaningfully and reciprocally to the other and in so doing, increase the level of group interaction or dynamics.

Results Experiment II

A Univariate Analysis of Variance on each of the variables in the two Group Dynamics measures was conducted using the SAS Statistical package (SAS Institute, 1999). As with Experiment I, there were two levels of fixed effects for Method and Facilitation. Given that the audiotape data (Group Dynamics Variables 1-4) were generated at the group-level and that the post-activity voting data (Group Dynamics Variables 5 and 6) were generated at the individual level, these two data types were analyzed separately. Each of the independent variables (Method and Facilitation) was modeled against each of the four comment types from Measure 1 and the two questions from Measure 2. The error term used for the four comment types on the Measure 1 analyses was the between group error term.

ANOVA Experiment II Measure I Results

Measure 1 - Dependent Variable 1

Analysis of Variance (ANOVA) results for the first dependent variable – Comments on Strategy - are presented in Table 4.

Table 4 ANOVA for Experiment II, Measure 1, Variable 1 - Comments on Strategy

Source	SS	df	MS	F
Between groups				
Method (M)	.15	1	.15	5.18**
Facilitation (F)	.00	1	.00	.09
Method x Facilitation	.08	1	.08	2.58
Group error	.29	10	(.03)	

* $p < .10$ ** $p < .05$ *** $p < .01$

Table 4 indicates that on the first group level variable used to assess Group Dynamics, a significant main effect occurred for Method $F(1, 10) = 5.18, p < .05$ with better performance observed in the Simulation conditions ($M_{\text{Case}} = 1.17, M_{\text{Simulation}} = 1.36$). No other significant effects were observed.

Measure 1 – Dependent Variable 2

Analysis of variance (ANOVA) results for the second group level variable - Comments on Process - are presented in Table 5.

Table 5 ANOVA for Experiment II, Measure 1, Variable 2 – Comments Related to Process

Source	SS	df	MS	F
Between groups				
Method (M)	.18	1	.18	3.47*
Facilitation (F)	.01	1	.01	.19
Method x Facilitation	.09	1	.09	1.74
Group error	.51	10	(.05)	

* $p < .10$ ** $p < .05$ *** $p < .01$

Method effects for Variable 2, Comments on Process, were found to be weakly significant $F(1,10) = 3.47, p < .10$, with better performance observed in the Case condition ($M_{\text{Case}} = .74; M_{\text{Simulation}} = .51$). No other significant effects observed.

Measure 1 – Dependent Variable 3

ANOVA results for the third variable in the group level Measure I – Comments related to Rationale - are presented in Table 6.

Table 6 ANOVA for Experiment II, Measure 1, Variable 3 - Comments Related to Rationale

Source	SS	df	MS	F
Between groups				
Method (M)	.85	1	.85	9.16**
Facilitation (F)	.16	1	.16	1.75
Method x Facilitation	.00	1	.00	.02
Group error	.93	10	(.09)	

* $p < .10$ ** $p < .05$ *** $p < .01$

Consistent with prior results, Method effects were strongly significant $F(1, 10) = 9.16, p < .05$, with better performance observed in the Case groups ($M_{\text{Case}} = 1.70; M_{\text{Simulation}} = 1.15$). There were no other significant effects observed.

Measure 1 – Dependent Variable 4

ANOVA results for Comments related to Facilitation are shown in Table 7.

Table 7 ANOVA for Experiment II, Measure 1, Variable 4 - Comments Related to Facilitation

Source	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>
Between groups				
Method (M)	.00	1	.00	.01
Facilitation (F)	.30	1	.30	5.40**
Method x Facilitation	.00	1	.00	.00
Group error	.54	10	(.05)	

* $p < .10$ ** $p < .05$ *** $p < .01$

In contrast to the first three Group Dynamics variables which showed a significant main effect for Method, only Facilitation showed a significant effect $F(1,10) = 5.40, p < .05$ on the last variable. Results were as expected, the Facilitated conditions had higher levels of facilitative comments than the Non-Facilitated groups ($M_{\text{Facilitation}} = .77; M_{\text{Non-Facilitation}} = .46$). There were no other significant effects observed.

ANOVA Experiment II Measure 2 Results

The second measure used to assess Group Dynamics was the anonymous voting procedure. In this assessment, individuals were asked to rate on a five-point scale their level of agreement with their group's final strategy and the degree to which they thought the strategy reflected their input. Unlike the first four group level variables that comprised the first measure of Group Dynamics, the two dependent variables that comprised the second Group Dynamics measure were based on data collected from each individual.

Measure 2 – Dependent Variable 5

Analysis of Variance results for the fifth dependent variable are shown in Table 8.

Table 8 ANOVA for Experiment II, Measure 2, Variable 5 – Level of Agreement with Final Strategy

Source	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>
Between subjects				
Method (M)	.11	1	.11	.07
Facilitation (F)	3.00	1	3.00	1.96
Method x Facilitation	.26	1	.26	.17
Subject error	82.75	54	(1.53)	

* $p < .10$ ** $p < .05$ *** $p < .01$

As can be seen in Table 8, no significant effects were observed for any factors.

Measure 2 – Dependent Variable 6

ANOVA results for the second variable assessing the participant’s perceived level of input on the group’s final strategy are given in Table 9.

Table 9 ANOVA Experiment II, Measure 2, Variable 6 – Level of Input on Final Strategy

Source	SS	Df	MS	F
Between subjects				
Method (M)	6.21	1	6.21	4.94**
Facilitation (F)	.75	1	.75	.59
Method x Facilitation	.20	1	.20	.16
Subject error	67.88	54	(1.26)	

* $p < .10$ ** $p < .05$ *** $p < .01$

As can be seen in Table 9, a significant Method main effect $F(1, 54) = 4.94, p < .05$ was observed. An examination of the mean scores for this variable indicated higher mean scores in the Simulation groups ($M_{\text{Simulation}} = 4.16; M_{\text{Case}} = 3.48$). No other significant effects were observed.

Summary of Experiment II ANOVA Results

Of the four types of comments analyzed on Measure 1 of Experiment II, a significant main effect for Method was found on comments of Strategy, Process and Rationale and a significant main effect was observed for fourth variable, Facilitative comments. No significant interaction effects between Method and Facilitation were found. Of the three variables that were significant under Method, the experimental conditions with the higher mean scores were not consistent across variables. The Simulation condition generated a greater number of comments of a Strategic nature while the Case groups had significantly more comments related to Process and Rationale. In the analysis of Measure 2 dependent variables, Method was significant for the second question on the voting procedure with the Simulation groups perceiving higher levels of input on their team’s strategy than individuals in the Case groups.

MANOVA Results for Experiment II

To the extent that the dependent variables used to measure Group Dynamics share commonalities both theoretically and empirically, a Multivariate Analysis of Variance (MANOVA) was conducted using the Measure 1 dependent variables. On this MANOVA, the four comment types for Measure 1 were modeled using the same two levels of Method and Facilitation used in the univariate analyses.

Results of the MANOVA on the Four Statement Types of Measure 1

Results of the MANOVA procedure on the four classifications of statements found to be significant in the ANOVA analysis were modeled as covariates as shown in Table 10.

Table 10 MANOVA Using the Four Group Level Dependent Variables

Source	Λ	df	F	η^2
Between groups				
Method (M)	.0727	4, 7	22.31***	.9273
Facilitation (F)	.4082	4, 7	2.54	.5919
Method x Facilitation	.2154	4, 7	6.37**	.7846

* $p < .10$ ** $p < .05$ *** $p < .01$

In keeping with results observed on the Univariate Analysis of Variance, the MANOVA analysis detailed in Table 10, also shows a significant main effect for Method $F(4, 7) = 22.31, p < .01$. However, the main effect for Facilitation observed on the ANOVA analysis for variable four – Facilitative Comments – was *not* significant on the MANOVA analysis. Finally, whereas there were no significant interaction effects between Method and Facilitation observed on the four ANOVA tests from Measure 1, when the four comment types were analyzed together a significant Method x Facilitation interaction effect $F(4, 7) = 6.37, p < .05$ emerged.

As there was only one variable of the two from the Measure 2 voting procedure that had significant effects on the ANOVA analysis, a Multivariate Analysis for this measure was unwarranted.

Summary of Results

While the focus of Experiment I was on the assessment of how the two methods and levels of facilitation affected mental models over time, in Experiment II, the focus shifted to understanding better the relationship between Method and Facilitation on Group Dynamics - a hypothesized moderator of mental model development. In this experiment it was proposed that the method used would *not* significantly affect the level of group dynamics observed in the group activity (H_{01} : Method). Further, it was asserted that the level of facilitation provided the group *would* lead to significant differences in group performance (H_{02} : Facilitation). Finally, it was hypothesized that the difference in group dynamics levels between Facilitation groups would differ according to Method level (H_{03} : M x F). These experimental hypotheses and the effect of the results may be summarized as follows in Table 11:

Table 11 Experimental Hypotheses Testing Results for Experiment II

Experimental Hypothesis	Test Results
H_{01} : The method used would not have a significant effect on Group Dynamics	Rejected
H_{02} : Facilitation of the group process would have a significant effect on Group Dynamics	Rejected
H_{03} : Time would have a significant Method x Facilitation interaction	Moderately Supported

On the first measure of the Group Dynamics assessment, the classification of the four types of comments from the audiotapes, there was a significant main effect for Method. Unlike the ANOVA analysis that showed no two interaction effects on the four group level variables, the MANOVA analysis showed a significant interaction effect for Method x Facilitation. Whereas the Facilitative comments (Variable 4) were significant in the ANOVA analysis of Measure 1, they were not significant on the subsequent MANOVA analysis. On Measure 2 of the Group Dynamics assessment, there was only one significant effect observed for Method. It occurred on the second variable of Measure 2 – Level of Input on Final Strategy. Since this was the only significant dependent variable on Measure 2, the individual level measure, a MANOVA analysis was not required.

Discussion of Results

The Experimental Hypotheses 1, asserting that there would *not* be a significant Method effect was rejected. Conversely, the Experimental Hypotheses 2, proposing there would be a significant effect due to facilitation was rejected. Experimental Hypothesis 3 pertaining to an expected Method x Facilitation interaction effect was moderately supported ($p > .01 < .05$).

The first hypothesis in Experiment II stating that there not would be a significant differences due to variations in Method was strongly rejected when subjected to multivariate analysis. The univariate analysis of variance showed that Simulation groups made significantly more comments related to Strategy and reported significantly higher levels of agreement on the final strategy whereas Case groups made more comments related to Process and Rationale - regardless of the level of facilitation provided. Although not significant in a multivariate sense, the differences in mean facilitative comments made was significant when analyzed by univariate ANOVA. Higher levels of Facilitative comments in groups where facilitation was provided supports the internal validity of the facilitation variable manipulation – when a facilitator was present, facilitative comments occurred, and when there wasn't a facilitator, facilitative comments were made significantly less often.

Results of the second experimental hypothesis asserting that there would be differences in the level of group dynamics as a function of facilitation provided were opposite what was projected. Results in the multivariate analysis showed that facilitation level alone did not result in significantly higher levels of group dynamics when all four dependent variables were simultaneously considered.

The third experimental hypothesis that the group dynamics differences between methods would differ significantly across facilitation levels was moderately supported ($p > .01 < .05$). Interestingly, in this situation, none of the dependent variables consisting of the four comment types (Strategy, Process, Rationale and Facilitative) used to measure group dynamics was sensitive enough on its own to detect a significant Facilitation x Method interaction on the univariate analysis. It was only when these variables were analyzed together as a system in the multivariate analysis that a significant difference between the four groups was observed. In general, no one group was shown to have consistently higher levels of several of the different comment types. Perhaps of most interest however, were the groups exhibiting the greatest levels of discussion on strategy alternatives and rationale for strategy – two theorized indicators of mental model content. Although not significant on the univariate ANOVA analysis, the significant MANOVA results showed that the Facilitated Case groups had higher levels of discussion on Rationale (ie., why proposed strategy would be effective) while the Non-facilitated Simulation

groups had more discussion on Strategy (ie., how to achieve desired outcomes). Facilitative comments were greatest in the Facilitated Case groups and comments related to Process were greatest in the Non-facilitated Case groups.

Integration of Experiment I and Experiment II Results

In order to better understand the results described above, Experiment II results need to be looked at in light of the results observed on the first experiment assessing mental models. The following paragraphs highlight some of the most important Experiment I outcomes and their potential relationship to results from the experiment described here. Overall, the most important, yet counterintuitive finding, was the differential shape of the univariate three-way Method x Facilitation x Time interactions across the Ratings Task I and II as shown in Figure 5.

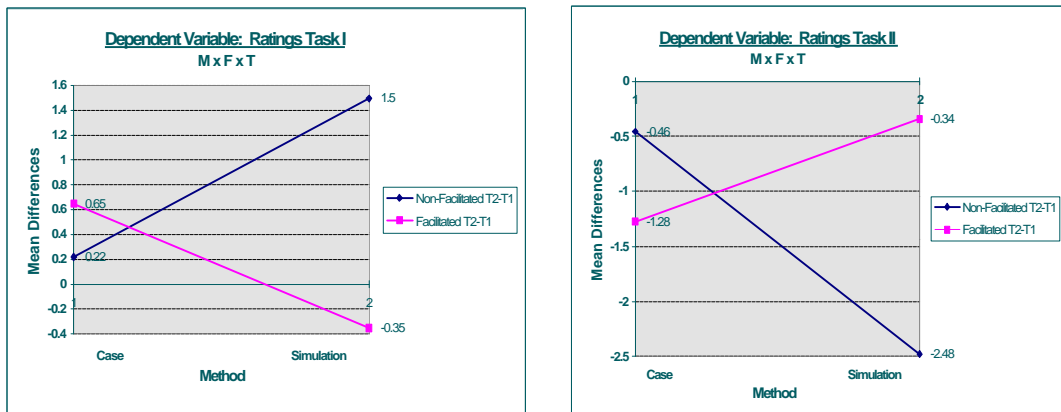


Figure 5 Pre- and Post Differences in M x F x T for Ratings Task I and II

When mean Time differences were compared across Method levels, the shape for Facilitation was reversed across the two ratings tasks. This was particularly evident in the Simulation groups where facilitation of the group resulted in a performance decrement on the first ratings task in contrast to a performance enhancement on the second ratings task. Even though the effect was not as striking, facilitation also had a reverse effect on the two ratings tasks in the Case conditions. Most puzzling perhaps was that the comparative effect observed in the Case groups was just the opposite of that observed in the Simulation groups, as facilitation appeared to suppressed performance on the first ratings task but to aid performance on the second task.

This contrast suggests that variations in performance may be due to differences in the nature and difficulty of the two ratings tasks. As noted previously, mean performance dropped for both the Facilitated and Non-facilitated groups on the second ratings task which asked subjects to indicate the level of influence they thought each of the six control variables would have on the three populations of people in the system. This task required that participants rate eighteen different paired combinations on a five-point scale. In comparison, the first ratings task required that participants rate six different combinations on a three point scale. Had the variations in performance between ratings tasks been consistent across case and simulation groups, differences in the complexity of task could explain the variations in performance on the two tasks. But because facilitation appears to have had an opposite effect on performance for each of the two tasks depending on the method used, it is necessary to look at the relationship between Method, Facilitation, and the measurement task.

Relationship between Experiment I and II

The analysis in Experiment II showed that comments related to process were highest in the Non-facilitated Case groups. This suggests that these groups may spend more time figuring out how to proceed with their activities than on the activities themselves. Interestingly, while there were no significant differences between groups in the level of Facilitative comments made as a function of method type, there were significant differences in the levels of Strategic, Process and Rationale comments based on the method used. This suggests that the nature of the discussion that occurred was affected by the method used during the group activity. These variations in types of comments given, may have contributed to differences in performance on the two ratings tasks as shown in Figure 5.

Relationship between the Ratings Task I and Comment Type as a Function of Method

As a starting point, recall the differences in complexity of the Ratings I and II tasks. On Ratings Task I, participants were asked to assess the effect of the six control levers on the system functioning overall, while on Ratings Task II they were asked to assess the effect the six control levers on each of the three populations of people presumed to exist in the hypothetical organization. The following paragraphs consider the differences in the complexity of these tasks in light of the nature of comments made during the group activity in each of the two method groups.

First, comments related to Strategy were found to be highest in Ratings Task I in the Simulation groups for Ratings Task I. Here, it could be asserted that feedback from the simulation allowed group members to identify the most effective levels of each variable to use to achieve the best overall performance – the objective of Ratings Task I. While the Case groups did not have the same level of reiterative performance feedback, this did not seem to be a detriment to performance in the Facilitated Case groups. Perhaps in these groups, a facilitator helped group members explore why their strategy would work and encouraged discussion on how the six variables would affect performance.

For Ratings Task I, in Non-facilitated Simulation groups, the pre-post mean improvement was more than twice that of the Facilitated Case group. Perhaps without facilitation, simulation groups had more time for trial-and-error, as there was no one urging them to discuss their rationale or the performance observed. This may have given these groups more information on system functioning that contributed to their better performance.

In contrast, comments related to Process were significantly higher in the Case groups. More time spent on process in the Case groups may have meant more point-by-point discussion of how each system control level would effect the overall system. Whereas Non-facilitated Case groups may have spent undue time discussing only a few of the control levers because more time was spent on group process, a facilitator in these groups may have ensured that ample time was given to more thoroughly completing the task by considering all variables. Indeed, the Facilitated Case groups mean differences on the Ratings Task I were second highest overall followed closely by the Non-facilitated Case groups. Further, in the Non-facilitated Simulation groups, comments related to Process were lowest and performance on the first ratings task was also lowest. This suggests that the Non-facilitated Simulation groups spent little time establishing an experimental process and tracking performance that would allow them to better understand the effects of the variables on system performance overall. Moreover, even when facilitation was provided, it made

little difference in increasing the amount of time spent on process. Thus it would appear that in Simulation groups it was *not* the facilitator that controlled the process.

Finally, comments on Rationale were found to be significantly higher in the Case groups on Ratings Task I. In these groups, more discussion of Rationale for strategy meant more discussion on the effect of the control levers on the system. This may have helped Case groups maintain high levels of performance on Ratings Task I, even without the performance feedback that would have been provided by the simulation. In contrast, in Non-facilitated Simulation groups where comments related to Rationale were lowest, performance on Ratings Task I was also lowest.

Relationship between Experiment I and Experiment II, Measure 1

On Ratings Task II, participants were asked to assess the effect that each of the six control levers would on each of the three populations of people presumed to exist in the hypothetical organization. Although all experimental groups exhibited a drop in performance on the Ratings II posttest, the Facilitated Simulation group still performed marginally better than other groups as can be seen in Figure 5 shown previously. As with Ratings Task I, facilitation of the group appeared to be the differentiating factor affecting performance. However, consideration should also be given to the types of comments made during the group model building activity as some comment types were found to be significantly greater as a function of method used. These differences in performance on Ratings Task II as a function of the types of comment that were shown to be significantly greater as a function of method groups are described in greater detail below.

First, comments related to Strategy as well as performance on Ratings Task II were significantly higher in the simulation groups. Here, output from the ‘runs’ of the simulation may have provided information that was helpful in understanding the how the strategy employed affected specific populations of people - the focus of Ratings Task II. However, even with this visual feedback cue, lacking a *process* for tracking these results participants in a simulation condition would find it difficult to retain the details of these runs over repeated trials.

Secondly, comments related to Process should also be considered in light of performance observed on Ratings Task II. While the Non-facilitated groups may have performed well on Ratings Task I as a result of both system feedback and opportunity for more uninterrupted trials, they had significantly lower levels of comments related to process. This finding supports the theory that, without a structure to track multiple trials, it was difficult to perform well on Ratings Task II. If so, then it would seem that adding a facilitator to simulation groups to help the group follow a structured experimentation process would lead to better performance. As such, the combination of feedback inherent to the simulation when combined with a facilitator to instill process should ensure more discussion on strategy and tracking of trials to better understand the more complex second order relationships measured on Ratings Task II. Certainly it would be tempting to accept this as an explanation as to why the Facilitated Simulation groups performed marginally better than the Non-facilitated Case groups, as the assertion that a facilitator would make up for the lack of attention paid to devising a process for experimentation was the theoretical supposition made in Chapter 2. The problem with this theory however, is that the Simulation groups had the *lowest* levels of discussion related to Process regardless of whether they were facilitated or not. Hence, even though the Non-facilitated Simulation groups had better performance on Ratings Task II overall, their performance was only marginally better than the

Non-facilitated Case groups that exhibited significantly higher levels of discussion related to Process. Perhaps the case groups systematically discussed each variable and its effects both on the system and on the specific populations of people.

The third comment type, comments pertaining to Rationale were also significantly higher in Case groups ($p < .05$) which supports the idea that Case groups systematically discussed each variable and its effects more than other groups. Moreover, attention paid to “why” a chosen strategy would affect the system variables in a particular way may have been influenced by the presence of a facilitator as theorized as it was the Facilitated Case groups that had the highest levels of comments of Rationale overall.

Relationship between Experiment I and Experiment II Measure 2

Lastly, in considering the relationship between the Ratings Task I and II tasks and the perceived levels of input on final strategy as reported on the individual voting measure in Experiment II, it was observed that even without higher levels of process or more detailed discussion of rationale, individuals in the Simulation groups felt the final strategy reflected their input significantly more than those in the Case groups ($p < .05$). This suggests that there were aspects of the Simulation method that were more effective than the Case method for drawing group members into the process and that they were involved in decision making.

Discussion of Unexpected Results

Results of the hypotheses proposed in Experiment II were surprising in several ways. First, the assertion made that Method would *not* significantly affect group dynamics had to be reconsidered in light of the statistical impact that Method did have on comments related to Strategy, Process and Rationale. Secondly, that Facilitation did not have a significant effect as theorized, was also surprising considering the emphasis placed on Facilitation in the literature. Finally, whereas Method did affect group dynamics but Facilitation did not, and whereas there was a significant interaction observed for Method x Facilitation on the MANOVA analysis for Experiment II, it may be theorized that method may mediate the effectiveness of facilitation.

What was revealed by the MANOVA analysis in Experiment II that was not evident in the univariate analysis was the effect that Method had on facilitative comments. Surprisingly, the greatest number of facilitative comments occurred in the Non-facilitated Simulation groups and the second highest level occurred in the Facilitated Simulation groups. Given that there were higher levels of Facilitative comments in the two simulation groups even though one was non-facilitated, suggests that there are inherent aspects of the simulation process that serve a facilitative function. Perhaps the participant in charge of keyboard input or the individual vocalizing the input values acts as an informal leader. That the simulation is structured with an item by item input field might also suggest that the man-machine interface serves to facilitate the group’s process and in so doing reduces the level of discussion related to process that is required. Given that Simulation groups spent significantly less time on discussion of process supports this idea.

Conversely, in the Case groups, the levels of Facilitative comments were lowest which is surprising given that without the simulation variable input process to drive the group’s activity as proposed above, it would seem that a facilitator would have much more impact on the group’s process. Perhaps the levels of Strategic and Rationale statements made served to reduce the level of facilitative comments that were possible. For instance, whereas Strategic comments which

were highest in Simulation groups could be expressed relatively quickly and in succession – “do this, try that, go higher with that, etc” comments explaining Rationale take longer to express as people are inclined to give examples, explain the meaning of words and clarify their opinions. Hence, while the short, succinct strategy comments made may lead to a greater level of understanding of overall system functioning, they may suppress the level of statements relating to rationale needed to develop a better understanding of the second order system complexities measured on Ratings Task II in Experiment I. This notion is supported by the differences observed on the individual level measures of group dynamics where those in the Simulation groups reported significantly higher levels of perceived input on the final strategy than those in Case groups but where no significant difference was observed in the level of *agreement* with the final strategy. In short, everybody had a say in the process in the Simulation groups but what is said is not necessarily heard, understood and agreed upon by others in the group.

How Results of Experiment II Fit with Earlier Studies

==>Insert how these results fit with Akkermans and Vennix finding that good communication coincided with fair to high levels of group consensus;.

==> Insert how these results fit with the assertion that it may be expected that individuals would perceive higher levels of input on a chosen strategy while at the same time perceiving lower levels of agreement with the strategy (based on findings by Doyle, et al.)

==> Insert discussion on how these results fit with the expectation that individuals would not perceive high levels of input from the process and discussion would center on just a few elements of the conceptual problem.

==> Insert discussion on how these results fit with the expectation that non-facilitated case groups would have lower levels of discussion regarding rationale for a chosen strategy.

==> Insert discussion on how these results fit with the expectation that there would be little time spent discussing outcomes of the experiments, and that trials would continue one after the other in search of better performance without exploration as to why the simulation model reflected the outcomes that it did in non-facilitated simulation groups.

==> insert how these results fit with the expectation that the facilitator would effectively increase the level of perceived input on the final strategy.

==> insert discussion on how results fit with the expectation that the Facilitated Simulation groups would perceive higher levels of input on and agreement with final strategy and levels of comments related to rationale and strategy would be greater than in the other three conditions.

Further Considerations for Results in Relation to Earlier Studies

Results of this study support Wolfe’s (1975b) findings that participants using simulations often failed to apply formal, rational analyses in devising a strategy and did not take the time to articulate the rationale for their strategy without being prompted to do so by a facilitator. As with behaviors observed by Wolfe, statements of Rationale were significantly lower in Simulation groups as a function of the method used.

Next, Wolfe’s (1973, 1975a) finding that effective communication aided performance on business gaming situations was also supported by this study although not in the same way. Whereas Wolfe noted that those groups that had higher levels of communications performed better, results here showed that even though the Case groups had more discussion related to Process and Rationale, this did not translate to significantly better performance on Experiment I,

Ratings Task I, as performance was actually better in the Simulation groups. Study results complement Wolfe's findings by showing that the *type of communication* affects performance. Where the level of discussion related to strategy was higher in the Simulation groups, performance was also significantly higher on the first ratings task. In contrast, in Case groups where discussion of Process and Rationale were higher, performance on Ratings Task I was actually lower whether facilitated or not. Finally, whereas the majority of findings are compatible with earlier works, the results of this study did not support the case versus gaming comparison made by Wolfe and Guth (1975), who found that the use of games in the teaching of business policy were superior to case studies but only if teacher guidance and structure were provided. In this study, Non-facilitated Simulation groups (a teacher-less gaming corollary) outperformed the Facilitated Case groups on Ratings Task I. However, whereas facilitation did not aid simulation performance on Ratings Task I, it appeared to have helped on Ratings Task II. This finding suggests that while Method and Facilitation interact, that the nature of the interaction may vary as a function of the measurement method.

Implications of Results for Theory, Research and Practice

The results and insights on how mental model development may be due in part to variations in the nature of group dynamics have implications for future theory development and research design. The following paragraphs highlight some of these implications.

First, responses given in Experiment I did not necessarily reflect the same level of thinking from pre- to posttest conditions. For instance, participants in the simulation conditions referred to "we" in their posttest responses on the open-ended question more often than the case groups, suggesting that the simulation activity was more effective at building a sense of team camaraderie. This team spirit may carry over to responses that were more in keeping with what "the team" rather than what the individual would say. When individuals indicated that they disagreed with the final strategy, their answers to "why" they did not agree sometimes indicated that there was a particular variable they wanted given more or less emphasis in the final strategy. Thus, an answer given to a question when phrased as "we think that..." may reflect one perspective, while the level of individual agreement with this strategy may reflect another.

Secondly, in this study, the effectiveness of facilitation varied depending on the tasks to be completed. This suggests that some tasks are better suited to a facilitative process than others and that the design of the group model building activity should reflect these considerations. Assuming that the nature of group dynamics may vary under different methods, consideration should be given to the goals of the model building exercise. If the goal is greater exploration of the system variables with less concern on team performance, using a facilitator might encourage greater exploration of rationale but allow less time for strategy trials.

Next, the recognition that differences in the effectiveness of facilitation may be due to variations in method and task has implication for future evaluative research. Results herein suggest that simply asking whether facilitation is better or worse is too narrow a research question. The evaluation paradigm needs to be extended to consider how facilitation effectiveness varies according to method and performance task. Lastly, generalizations regarding facilitation practice must be limited to those situations that most closely match the fixed levels of method and facilitation employed here.

Lessons Learned: Practitioner Guidelines

Opting to emphasize model conceptualization or simulation processes independently of one another is at best a satisficing practice. This is not to say that it should not be done, but rather that the trade-offs in utilizing one aspect of the system dynamics model building paradigm at the expense of others should be recognized. Based on this assessment, the appropriate method and level of facilitation can then be matched to the learning objectives.

In determining the level of facilitation required, consideration should first be given to the method to be employed. If the goal of the group modeling activity is to teach about system complexity, results from Experiment I suggest that a facilitator will not have as much impact in a conceptual modeling activity based on a case study as they will in a simulation activity. Based on results of Experiment II detailed here, it can be expected that case groups will spend more time devising a process for going about the modeling activity with or without a facilitator. However, the same can not be said for simulation groups that will spend little time devising a process to systematically test components of the system. In using a simulation without a facilitator, groups can be expected to spend little or no time attempting to understand why their strategy affects system performance the way it does and will opt instead to run as many trials as possible in the time allotted.

Furthermore, case groups can be expected to consider more carefully the rationale behind presumed system relationships even in the absence of a facilitator. They may however, spend a great deal of time establishing a process to do this. Therefore, if exposing relatively inexperienced group members to all the primary relationships in a given system is the goal of the initiative, a facilitator may be instrumental in ensuring timely completion of the process. If, on the other hand the session is designed to improve understanding of second order system relationships with groups whose members have greater expertise, facilitation may be superfluous. Finally, there are secondary benefits that may be derived from using either a case study or a management flight simulator. For instance, these methods may be incorporated into a larger systems thinking learning initiative or serve as a vital introduction to a related organizational change effort. As such, they may play a critical role in achieving a specific organizational rather than individual learning objective. Given the contrast in the effect of facilitation on performance across the different mental model measurements used in Experiment I, facilitation of the process is clearly important and should be tailored not only to the methods used, but to the learning agenda.

==> Insert References